SIGNIFICANCE OF LABORATORY TESTS OF COAL AND COKE FOR COMBUSTION

COMPILED BY J. F. BARKLEY

* * * * * * * * * * Information Circular 7619

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

Work on manuscript completed June 1951. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7619."

September 1951

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

SIGNIFICANCE OF LABORATORY TESTS OF COAL AND COKE FOR COMBUSTION

Compiled by

J. F. Barkley[1]

CONTENTS

		Page
Foreword		1
I.	Significance of laboratory tests of bituminous coal for pulverized-coal firing	4
II.	Significance of laboratory tests of bituminous coal for end-dump underfeed stoker firing	12
III.	Significance of laboratory tests of bituminous coal for spreader-stoker firing	16
IV.	Significance of laboratory tests of bituminous coal for chain-grate stoker firing	19
V.	Significance of laboratory tests of bituminous coal for side-dump commercial and industrial underfeed stoker firing	21
VI.	Significance of laboratory tests of bituminous coal for locomotive firing	23
VII.	Significance of laboratory tests of bituminous coal for hand firing	27
VIII.	Significance of laboratory tests of bituminous coal for residential stoker firing	30
IX.	Significance of laboratory tests of anthracite for pulverized-coal firing and for traveling- and chain-grate stoker firing	34
X.	Significance of laboratory tests of anthracite for medium-sized industrial and residential-stoker firing	37
XI.	Significance of laboratory tests of anthracite for hand firing	38
XII.	Significance of laboratory tests of coke for traveling- and chain-grate stoker firing	41
XIII.	Significance of laboratory tests of coke for domestic stokers and hand firing	43

[1] Chief, Fuels Utilization Branch, Bureau of Mines, U. S. Department of the Interior.

Information Circular 7619

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

FOREWORD

The following series of papers on the combustion of coal and coke were prepared as part of a broad project on the Significance of Tests of Coal and Coke assigned to Subcommittee XVII of Committee D-5 on Coal and Coke of the American Society for Testing Materials. The aid of highly experienced fuel engineers was enlisted to prepare papers covering the significance of the tests as related to combustion. The membership of this group is as follows:

J. F. Barkley, Chairman
Chief, Fuels Utilization Branch
U. S. Bureau of Mines
Washington, D. C.

E. D. Benton, Director
Division of Research & Fuel Engineering
Ohio Coal Association
Cleveland, Ohio

R. J. Brandon, Fuel Engineer
Detroit Edison Co.
Detroit, Mich.

W. A. Carter, Technical Engineer of Power Plants
Detroit Edison Co.
Detroit, Mich.

C. H. Frick, Manager
Coal Bureau
Pennsylvania Power & Light Co.
Allentown, Pa.

A. E. Grunert, Chief Operations Engineer
Commonwealth Edison Co.
Chicago, Ill.

C. F. Hardy, Chief Engineer
Appalachian Coals, Inc.
Cincinnati, Ohio

Douglas Henderson, Vice President
Fuel Engineering Co.
New York, N. Y.

A. J. Johnson
Fuels and Combustion Consultant
Lansdowne, Pa.

4402

Generated on 2024-09-20 07:37 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Dr. R. C. Johnson, Vice President in Charge of Research
Anthracite Institute
Wilkes-Barre, Pa.

H. W. Nelson, Supervisor, Fuel Research
Battelle Memorial Institute
Columbus, Ohio

T. E. Purcell, Gen. Supt., Power Stations
Duquesne Light Co.
Pittsburgh, Pa.

C. H. Sawyer, Research Engineer
Eastern Gas & Fuel Association
Pittsburgh, Pa.

C. E. Shaffer
Research Engineer
Koppers Co.
Verona, Pa.

The purpose of these papers is to answer, in so far as practicable, questions as to the significance of A.S.T.M. laboratory tests in the combustion of coal and coke. Attempt is made to show in what way these tests may be of value in connection with the use of the fuel. It should be realized that the subject matter is not scientifically clean-cut and definite, and in many instances the best that can be written is only relative or indicative.

The following laboratory tests and classifications have been considered:2/

Laboratory Tests on Bituminous Coal

1. Proximate analysis (H_2O, V.M. - F.C. - ash).
2. Ultimate analysis (C-H-O-N-S - ash).
3. Calorific value (B.t.u.)
4. Fusibility of ash (initial deformation - softening - fluid).
5. Analysis of ash (phosphorus).
6. Fineness of powdered coal (size consist).
7. Grindability.
8. Drop-shatter test (size stability and friability).
9. Tumbler test (friability).
10. Screen analysis (size consist).
11. Weight per cubic foot of crushed coal.
12. Dustiness of coal.
13. Free-swelling index.
14. Agglutinating value.

Classification

15. Rank (low- and medium-volatile bituminous, high-volatile A bituminous, etc.).
16. Variety (common banded, splint, cannel, and boghead).

2/ See A.S.T.M. Standards on Coal and Coke, published by the American Society of Testing Materials, Philadelphia, Pa.

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Laboratory Tests on Anthracite

1. Proximate analysis (H_2O, V.M. - F.C. - ash).
2. Ultimate analysis (C-H-O-N-S - ash).
3. Calorific value (B.t.u.)
4. Fusibility of ash (initial deformation - softening - fluid).
5. Analysis of ash (phosphorus).
6. Fineness of powdered coal (size consist).
7. Grindability.
8. Screen analysis (size consist).

Laboratory Tests on Coke

1. Proximate analysis (H_2O, V.M. - F.C. - ash).
2. Ultimate analysis (C-H-O-N-S - ash).
3. Calorific value (B.t.u.)
4. Fusibility of ash (initial deformation - softening - fluid).
5. Analysis of ash (phosphorus).
6. Volume of cell space of lump coke.
7. Drop-shatter test (property to withstand breakage).
8. Tumbler test (resistance to degradation by abrasion).
9. Sieve analysis (size consist).
10. Weight per cubic foot.
11. Dustiness of coke.

Because the significance of the tests varies appreciably with different types of fuel-burning equipment, papers were prepared for the following types:

Bituminous coal:

I. Pulverized-coal firing.
II. Multiple-retort, end-dump, underfeed stokers.
III. Spreader stokers.
IV. Chain-grate stokers.
V. Single- and multiple-retort, side-dump, underfeed stokers.
VI. Locomotive firing (stoker and hand firing).
VII. Hand firing (other than locomotive).
VIII. Residential stokers.

Anthracite:

IX. Pulverized-coal firing and traveling- and chain-grate stokers.
X. Medium-sized industrial and residential stokers.
XI. Hand firing.

Coke:

XII. Traveling- and chain-grate stokers.
XIII. Domestic stokers and hand firing.

Pending further required action of Committee D-5 on the complete project, publication of these papers as a Bureau of Mines information circular was agreed upon. The authors of the papers invite comments and discussions.

4402

Generated on 2024-09-20 07:38 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

I. Significance of Laboratory Tests of Bituminous Coal

for

PULVERIZED-COAL FIRING

by T. E. Purcell

1. PROXIMATE ANALYSIS

(a) Moisture. - Moisture, "as fired," is specifically significant in pulverized coal firing because of its effect upon the continuity of raw-coal feed to the pulverizer, pulverizer capacity, flame stability, and speed of ignitio

The extraneous moisture content is a rough index of potential difficulties in unloading and maintaining the flow of raw coal to the pulverize and of pulverized coal to the furnace, with the troubles increasing geomet rically as the percentage increases. Sticking or other stoppage of coal flow at any point between the bunker and the furnace is especially serious with pulverized-coal firing because there is danger of immediate loss of output. Where moisture is a problem, the designer must exercise great car in the design of coal-handling and preparation apparatus.

All other things being equal, the moisture content, especially extraneous moisture, is an index of pulverizer capacity, and therefore of boile capacity. All types of pulverizers are affected to some extent by extraneous moisture, some to the point of ceasing to function completely. Excess pulverizing capacity and means for adequately drying the coal allevia the adverse effects.

Sticking and plugging in pulverized coal-transport pipes and in the bunkers and feeders of bin-type systems because of recondensation of moisture are additional hazards of high-moisture coal.

High total moisture adversely affects flame stability, thus reducing the safe operating range of the boiler, and may cause delayed ignition, which could result in increased unburned-carbon loss and a greater tendenc to foul the convection surfaces of the boiler.

Although the average moisture in coal for pulverized-coal firing is o great significance, it is the high extreme of moisture likely to be encoun tered that is of greatest importance to both the designer and the operator It is frequently the practice, in purchasing coal for suspension burning, to reserve the right to reject shipments exceeding some critical value of moisture.

Other significances of moisture, such as increased corrosion in the presence of sulfur and its combustion products, lowering of the calorific value of the coal, and increased stack losses by reason of latent and sensible heat loss, apply equally to pulverized-coal firing and all other types of firing.

(b) Volatile matter and fixed carbon. - As pulverized coal is injected into a hot furnace, the volatile matter is distilled off as a mixture of complex hydrocarbon gases. These gases have a relatively low ignition temperature and, when intimately mixed with enough oxygen, ignite readily, burn rapidl

Generated on 2024-09-20 08:51 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

and produce a highly stable, short, bushy flame. The burning volatile matter, in turn, provides the kindling action to ignite the fixed or free carbon in the remaining solid particles of fuel. The free carbon has a relatively high ignition temperature, is less easily brought into intimate contact with oxygen, and therefore inherently ignites less readily, burns more slowly, and produces a less stable, longer flame. The solid particles containing the free carbon must be permitted enough time in a region of high temperature and in contact with an ever-renewing supply of oxygen in order to burn completely.

How the volatile content and its complementary fixed carbon content affect the design of pulverized fuel-firing equipment for a given coal, the choice of coal with a given design, or the operating procedures, capacity, performance, and efficiency with a given design and a given coal may be inferred from a consideration of the dissimilar combustion processes described above.

Generally, the high-volatile coal is more difficult to grind and therefore affects the capacity of the steam-generating unit through its effect upon pulverizer capacity, but this aspect will be discussed more properly under "Grindability." Similarly, the volatility of a coal has a bearing on its heat content, and the attendant effect upon capacity will be discussed under "Calorific Value."

The volatile content affects the design of burners and the relationship between primary and secondary air quantities and velocities at the burner. There must be a velocity of primary air sufficiently in excess of the speed of flame propagation to prevent the volatile flame from damaging the burners. There must be enough primary air properly mixed with the volatile matter to burn the volatile immediately upon entrance into the hot furnace in order to prevent "cracking" of the hydrocarbons into hydrogen, which immediately burns to water, and finely divided "carbon black," which is likely to pass up the stack as smoke, being practically noncombustible except under high temperature and an atmosphere rich in oxygen. The percentage of volatile matter is therefore a general index of the smoke-producing potentiality of a coal.

Low-volatile coal requires a greater proportionate quantity of low-velocity secondary air and less primary air. This may lower the capacity of the pulverizer because of insufficient coal pick-up or may cause delayed ignition because of inadequate evaporation of moisture in the mill; under this condition, a higher primary air temperature with resulting larger volume would promote drying and coal pick-up.

The percentage of free carbon is a rough index of the unburned-carbon loss. As the percentage of free carbon increases, finer grinding is necessary in order to limit the unburned-carbon loss to a given value. Finer grinding requires either a larger pulverizer or lowered output. Finer grinding promotes ignition and rapid burning, as does the provision of a hotter furnace, especially near the burners, by means of a reduction in the water wall cooling surface and an increase in the refractory surface. At the same time, the combustion rate must be lower, either by providing a larger furnace for a given steam output or by reducing the output from a given furnace, in order to allow sufficient time for more complete burning of the fixed carbon. Delayed ignition or inadequate time for complete

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

burning not only increases the unburned-carbon loss but also may cause or aggravate slagging at the entrance to the convection zones of the boiler; the burning particles, being above the "sticky" temperature of the incombustible matter, are more likely to adhere to convection surfaces.

From the foregoing, it is seen how the percentage of volatile matter can affect the absolute or the desirable maximum capacity of a given steam-generating unit in several different ways. Another item of greatest pertinence is the inherently greater stability of the flame produced by coal with a high volatile content and the lesser stability of that produced by coal with a high free-carbon content. This is essentially a matter of the relative rates of heat evolution and absorption during burning and the respective ignition temperatures of the two constituents. The question of flame stability places a lower safe limit on the combustion rate and steam output below which there is danger of losing the fire. The satisfactory operating range of output with a given furnace is thus intrinsically greater with high-volatile coal.

The foregoing is not to imply that one type of coal is inherently better than another type; equally desirable results may be obtained with any type of coal, provided the design and operation are properly coordinated with the specific coal characteristics. Such coordination, of course, must ultimately be based upon actual burning tests of a given type of coal in given or similar equipment.

The significance of the volatile content is greatest in the design of equipment, in the selection of coal to be burned in existing equipment, and in pointing the direction for changes in operation or operating compromises that may be necessary when changing fuel sources.

(c) Ash. - The proportion of ash or incombustible material in the coal is specifically significant in pulverized-coal firing because of its effect upon the rate of slagging and fouling of boiler surfaces, the unburned-carbon loss, the aggravation of the fly-ash nuisance value of the plant, the flame stability and speed of ignition, the burden placed on ash handling and disposal facilities, the erosion of boiler surfaces, ducts, fans, etc., and the capacity and rate of wear of pulverizers.

All other things being equal, the rate of slagging and fouling of boiler heat-transfer surfaces is more or less in proportion to the ash content of the coal. This, in turn, affects the requirement for cleaning facilities, the arrangement or spacing of convection-heating surfaces, the boiler outage time, and the expense of cleaning. The maximum capacity of the steam-generating unit may be affected either directly by reason of the burden placed upon the draft equipment or indirectly by the effect upon boiler efficiency. The superheat characteristics of the unit may be appreciably upset.

The unburned carbon is closely bound up with the solid particles of incombustible material, and this loss is at least directly proportional to the amount of ash in the coal.

The burden placed on ash-handling equipment and disposal facilities is directly proportional to the ash content of the coal and occasionally, in this respect, places a limit on the maximum sustained capacity of the boiler.

Generated on 2024-09-20 07:31 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The percentage of ash in the coal has some effect upon flame characteristics in suspension burning, but this aspect is not generally critical, even up to moderately high values. With very high ash, however, flame instability at low outputs is increased, and therefore the boiler operating range is narrowed, and the speed of ignition may be slowed with further increase in the fouling rate and the unburned carbon loss.

In pulverized-coal firing the greater portion of the incombustible material passes through the boiler with the combustion gases as fly ash. Whatever the means and efficiency of fly-ash collection, the public-nuisance value of the ash emitted to the atmosphere is aggravated in proportion to the percentage of ash in the coal. The passage of the fly ash through the equipment, of course, affects the erosion rate on the boiler surfaces, ducts, fans, etc.

The rate of wear of the pulverizer parts and the cost of its maintenance is more or less proportional to the ash content and is especially affected by extraneous inclusions - actual particles and lumps of incombustible not closely associated with the coal substance. These also may appreciably alter the grindability of the mixture and therefore the capacity of the pulverizer, in addition to the effect upon capacity by reason of the mere displacement of combustible with incombustible material. The ash content affects the capacity of other coal-handling equipment because of changed calorific value.

Total Incombustible

When the sum of the ash and moisture percentages exceeds 35 percent with high-rank coals, the factors of flame stability, speed of ignition, and unburned-carbon losses must receive special consideration in the design of furnace and burners and in pulverizers.

2. ULTIMATE ANALYSIS

With the exceptions noted in the items below, the ultimate analysis in itself is not of special significance in pulverized-coal firing. It is, of course, required in order to determine the combustion air requirements, the properties of the products of combustion, the sizing of air- and gas-handling equipment, and in complete heat-balance tests of the steam-generating unit.

(a) Carbon. - The percentage of total carbon in the coal has no special significance in pulverized-coal firing.

(b) Hydrogen. - Although the percentage of total hydrogen in the coal is not of special significance in pulverized-coal firing, it is of enough importance to warrant discussion. Relatively small percentages of hydrogen produce relatively large quantities of water vapor, which, upon condensation in the lower temperature regions, causes corrosion and plugging of gas passages with wet fly ash. The greater the percentage of hydrogen, the higher the temperature at which condensation and the resulting troubles occur. This limits the temperature to which flue gases may desirably be cooled and thereby limits boiler efficiency. The latent and sensible heat of the water vapor accounts for a considerable percentage of the total stack losses.

Generated on 2024-09-20 07:30 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(c) Oxygen. - A high percentage of oxygen indicates a lesser tendency of the coal to coke and cake during the combustion process, and therefore, all other things being equal, the unburned carbon loss may be expected to be less.

(d) Nitrogen. - The percentage of nitrogen in coal has no known significance in pulverized-coal firing.

(e) Sulfur. - Sulfur usually exists in coal as pyritic sulfur, sulfates, and organic sulfur and is usually reported with the proximate analysis. Coals high in sulfur are always regarded with suspicion until a thorough burning trial in a given equipment proves the absence of troubles with slagging and fouling. Pyritic sulfur, or sulfur in combination with iron, tends to lower the fusion temperature of the ash, the significance of which is discussed under "Fusibility of Ash."

Sulfur in any form in the presence of moisture may result in corrosion of coal-handling equipment. The products of combustion of sulfur, either SO_2 or SO_3 in combination with water vapor, raises the dew point of the combustion gases, and in order to avoid condensation the temperature to which the gases are cooled must be limited, with a corresponding detrimental effect upon boiler efficiency. If condensation is allowed to take place, plugging of the lower-temperature gas passages with fly ash is likely to occur, and corrosion is likely to be accelerated. Corrosive action to some degree during start-up and shut-down of boilers is unavoidable when the coal contains appreciable amounts of sulfur.

Sulfur in combination with iron is associated with furnace-tube erosion in zones in which a reducing atmosphere prevails and heat-absorption rates are high. Sulfur dioxide (SO_2) and sulfur trioxide (SO_3) in the stack gases can be obnoxious to both operators and the public, and there is some indication that these constituents accentuate the cloud or plume type of emission from stacks.

The wear on pulverizer parts and the cost of pulverizer maintenance are practically in direct proportion to the pyritic sulfur content because of its abrasiveness.

In the slag tap or wet-bottom type of pulverized-coal furnace, which is designed specifically to burn low ash-fusion temperature coal successfully, masses of metallic iron from the pyritic sulfur gradually accumulate on the bottoms and necessitate periodic outages for removal by chipping and drilling.

3. CALORIFIC VALUE

The calorific value of a coal, or B.t.u. per lb., "as weighed for billing" is the only measure of its potential value as a fuel per unit of cost. The actual value of a coal must be based, of course, not only on the potential value but must also include such utilization factors as its effect upon boiler capacity, on boiler efficiency, operating cost, cleaning cost, and maintenance cost. The calorific value is also one of the basic data in boiler-efficiency tests.

The B.t.u. "as fired," whether affected by moisture, ash, or characteristics of the coal substance itself, is a basic factor in determining the required size of coal-handling, preparation, pulverizing, and burning equipment; conversely, barring

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

other limiting factors, the calorific value fixes the maximum obtainable output from a given installation.

Coals of low calorific value, all other things being equal, are somewhat more difficult to ignite and produce a less stable flame, which narrows the satisfactory operating range of the boiler at the low-output end.

4. FUSIBILITY OF ASH

Whether or not a given coal will cause excessive slag formation and fouling in a given furnace and boiler, perhaps even lowering the boiler capacity by choking off the gas passages, whether or not the slagging will seriously affect the boiler efficiency, upset the superheat characteristics of the unit, necessitate more frequent and more expensive cleaning, and add to the possibility of mechanical damage from large masses of falling slag - these are the most significant questions in determining the suitability of a coal for a given equipment. Generally, the only adequate determination is by means of an actual performance test under operating conditions.

From a design viewpoint, the behavior of the ash in regard to slagging determines the furnace design, the arrangement and spacing of the heat-absorbing surfaces, and the necessary provisions for cleaning. The design of pulverized coal furnaces in this respect has settled in two well-defined trends: in the dry-bottom type the prevention of slag formation anywhere is aimed at by maintaining relatively low combustion rates and providing maximum furnace cooling, most advantageously arranged, whereas in the wet-bottom type the ash is intentionally melted and withdrawn as a fluid. In both types it is important that the temperature of the furnace exit gases and ash particles be lower than their "sticky" temperature to avoid accumulation of deposits.

The significance of the ash-fusion temperatures, as determined under laboratory conditions, lies in the extent to which these will predict the slagging behavior of the ash. These tests do determine the broad suitability of low-fusion temperatures for wet bottoms and high-fusion temperatures for dry bottoms, but within each range the correlation between temperature and behavior is frequently poor and frequently inconsistent.

The above lack of close correlation may be ascribed to a number of causes - the relatively wide range of precision in the laboratory determinations, the inability to duplicate actual furnace conditions in the laboratory, selectivity or segregation in the furnace of various constituents of the ash having widely different fusion temperatures, natural variability of the coal, etc. Here it should be mentioned that an oxidizing atmosphere is more representative of conditions in pulverized coal furnaces, and the fusion temperatures usually are higher in such an atmosphere, especially for an ash high in iron. For pulverized-coal firing, laboratory determinations of fusion temperatures should always include tests in an oxidizing atmosphere.

The significances of the three individual fusion temperatures as generally reported - keeping in mind, of course, the limitations in their interpretation - are as follows:

(a) The initial deformation temperature is a warning temperature at which ash might adhere to cold surfaces and the temperature to which gases should be cooled before they reach surfaces in passages subjected to obstruction.

(b) The softening temperature is the temperature at which the interpretations placed on the initial deformation temperature become more positive and the warning as to adherence becomes more strident. If the temperatures at critical points in the furnace equal or exceed the softening temperature, the design must be altered or the capacity must be decreased for a given coal.

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(c) The fluid temperature is the temperature at which the ash will flow and the temperature above which the ash in slag tap furnaces must be maintained. As the furnace temperature varies with the combustion rate, the fluid temperature places a lower limit on the operating range of wet bottom-type furnaces.

The range between initial deformation and fluid temperature has some significance in the operation of slag tap furnaces. Here the requirement for molten ash in one section and dry ash at the furnace exit indicates the use of a coal having a comparatively narrow range between these temperatures.

5. ANALYSIS OF ASH

The elements in the ash exist in complex combinations, the make-up of which undoubtedly depends on conditions during the combustion process. Samples of laboratory-produced ash from the same coal may show considerably different combinations.

The constituents of the ash have considerable significance in the efficiency performance of electrical-type fly-ash collectors. Marked differences in performance with different coals occur but research is needed to determine the precise correlation between ash analysis and collector performance.

The analysis of the ash has a secondary significance in accounting for differences in ash-fusion temperatures. Iron oxide, especially in excess of about 20 percent, may lead to slagging troubles and, in a reducing atmosphere, erosion of surfaces over which the slag flows.

6. FINENESS OF POWDERED COAL

With a given design of burner and furnace and a given type of coal, some control of flame stability, flame volume, completeness of combustion of the fixed carbon, and to some extent slagging at the furnace exit may be effected by controlling the fineness of pulverization, especially the proportion finer than 200 mesh. The finer the grind, the greater the stability, the shorter the flame, and the more complete and faster the burning of the fixed carbon.

The size and type of pulverizer required to serve a given steam generator is affected by the desired degree of fineness. The operator of existing equipment can control the fineness only by varying the output.

In conjunction with the grindability of the coal and the size consist of the raw-coal feed, fineness tests afford a performance check on the operation, proper adjustment of the classifying system, and maintenance of the pulverizing equipment.

Generally, the percentage retained on a 50-mesh screen and that passing through a 200-mesh screen are considered to be the most important determinations. The plus 50-mesh portion is difficult to burn completely, even under optimum conditions, whereas too great a portion finer than 200 mesh may indicate unnecessarily wasteful power consumption and rapid wear of the pulverizer; the exact degree of fineness is a matter of operating judgment and economic balance between pulverizing cost and burning losses.

The burning of large particles of coal in slag tap furnaces, which fall to the bottom, promotes the formation of masses of metallic iron, which are difficult and expensive to remove.

Generated on 2024-09-20 07:35 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

7. GRINDABILITY

Grindability, an index of the relative ease with which different coals may be pulverized in a prescribed laboratory procedure, is of significance in that it provides a basis by means of which, together with other data such as fineness, moisture, size of feed, etc., the designer determines the size and power requirements of the pulverizer and the operator checks the adjustment, operation, and maintenance of the pulverizer.

The grindability is of greatest significance in predicting the capacity of an existing pulverizer with a different coal in those cases in which pulverizer capacity may be the limiting factor in boiler output.

The exact correlation between grindability and pulverizer capacity must be determined by actual test for each type of commercial pulverizer. Generally, capacity is not strictly proportional to grindability for a given type.

8. DROP-SHATTER TEST

The drop-shatter test has no special significance in pulverized-coal firing.

9. TUMBLER TEST

The tumbler test has no special significance in pulverized-coal firing.

10. SCREEN ANALYSIS

The screen analysis is significant as a basis for checking the operation and maintenance of coal crushers, which generally precede the pulverizer. The screen analysis of the coal feed to the pulverizer is also a factor in pulverizer capacity and performance.

The screen analysis is frequently of great significance, in that pulverized-coal-fired equipment is often able to utilize fuels in the less desirable sizes, and this factor has a bearing on coal price.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL

The density of coal has no greater significance in pulverized-coal firing than it has in other types of firing.

12. DUSTINESS OF COAL

The test for dustiness of coal has no greater significance in pulverized-coal firing than it has in other types of firing.

13. FREE-SWELLING INDEX

The free-swelling index has some significance in pulverized-coal firing, in that a coal with a strong tendency to coke and to swell may be more difficult to burn completely in suspension, and corrective measures such as reduction of the combustion rate or increase in the fineness of grinding may be necessary. The difficulty in burning completely is augmented if it produces low-density particles, which are more readily carried out of the furnace before combustion is complete.

Generated on 2024-09-20 08:45 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

14. AGGLUTINATING VALUE

The agglutinating value has no known significance in pulverized-coal firing.

15. RANK

The rank of a coal is of secondary significance in pulverized-coal firing, in that, lacking an analysis particularly of volatile content, the broad suitability of a coal for a given equipment may be estimated by means of the rank.

16. VARIETY

The variety of a coal is of secondary significance in estimating the broad suitability of a coal for a given equipment and sometimes in accounting for anomalies of operation. For instance, cannel-coal admixtures (cannel coal is seldom used as a commercial steam fuel) produces sparklers in pulverized-coal furnaces, and lack of knowledge of its presence leads to erroneous conclusions concerning the average degree of pulverization and the magnitude of the unburned-carbon loss.

II. Significance of Laboratory Tests of Bituminous Coal for END-DUMP UNDERFEED STOKER FIRING

by R. J. Brandon and W. A. Carter

In the selection of coal for burning on underfeed stokers, the various chemical and physical properties and characteristics of coals must be known if purchase and utilization of coals are to be intelligent. Owing to differences in boiler and stoker design, in coal-burning rates to be maintained, and in experience of stoker operators, it is only possible to relate in general the significance of laboratory tests to the effects of coals on underfeed-stoker performance, efficiency, and maintenance.

1. PROXIMATE ANALYSIS

(a) Moisture. - Besides displacing useful heating value, moisture in coal usually is a detriment in both handling and burning. With high surface-moisture values, trouble usually is encountered in unloading coal from cars, plugging of coal-handling chutes and stoker hoppers, and in freezing of coal in winter. In regard to stoker performance, coal feed to sections of the stoker may be stopped with the result that parts of the grate area may become bare and maintenance cost increases because burned and warped iron must be replaced. In regard to the efficiency of steam generation, it is necessary to evaporate and, usually, superheat the moisture, with resultant loss of heat.

(b) Volatile matter and fixed carbon. - In a general way, the volatile matter of the coal is somewhat of an indication of the coking properties of the coal, as the low-volatile coals usually exhibit stronger coking properties than the higher-volatile coals. The design of the stoker equipment and the load to be carried will dictate whether coals with different volatile-matter contents can be burned; the test is of value in a broad determination of whether high- or low-volatile coals will be selected and will perform satisfactorily on a particular stoker. When considering the loss

Generated on 2024-09-20 07:32 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

in efficiency that may be caused by incomplete combustion of the volatile matter, it is necessary to consider furnace design and the introduction of overfire air together with stoker fuel-bed conditions. Since up to 30 percent of the heat in the coal may be contained in the volatile matter, a small amount of the high heating-value constituents of the volatile matter that escape without being burned can affect the over-all steam-generating efficiency considerably. Fixed carbon and volatile matter are considered together in fuel selection as the total combustible of the coal, as shown by the proximate analysis.

(c) Ash. - The quantity of ash in the coal decreases proportionately the amount of energy-producing material in each ton of coal. Any increase in ash content requires the handling, removal, and disposal of larger quantities of material, with resultant increase in operating and maintenance expense. Usually, the efficiency of the boiler unit decreases when high-ash coals are burned, owing to the increased amount of combustible carried into the refuse. Unless the coal contains enough ash to protect the grates on underfeed stokers, overheating of the iron results with consequent high stoker maintenance and boiler outage. When high-ash coal is burned, a larger percentage of the fuel bed consists of ash, which tends to retard combustion, and it may be impossible to feed enough high-ash coal into the furnace to generate the steam required. Increased ash content also reduces the coking properties of the coal, which may affect boiler operation and efficiency if a strongly coking coal is required for the rating to be carried.

2. ULTIMATE ANALYSIS

The ultimate analysis of coal gives a better representation of its composition by breaking down the organic part of coal into the basic chemical elements. In calculating the efficiency with which coal burns, the ultimate analysis is necessary. The quantity of oxygen, as shown by the analysis, does have a general significance for coal selection. High-oxygen coals usually are free-burning and may not possess the required coking properties for satisfactory fuel-bed performance on the underfeed stoker. Although the sulfur content is not usually a reliable guide for predicting ash-fusion characteristics, high-sulfur coals should be suspected of having low ash-fusion temperatures until burning tests show differently. As regards the effect of the sulfur content of the coal on steam generation efficiency, the permissible final temperature of the flue gas leaving the economizer or air heater depends on the sulfur content of the coal fired. There is an attainable low limit of flue-gas temperature below which the dew point is reached, with resultant costly corrosion. That is, because of the sulfur in the coal it will be necessary to replace equipment, which will be costly, or some efficiency of the boiler unit must be sacrificed. The second alternative usually is accepted as being less expensive.

3. CALORIFIC VALUE

From coals with identical analytical properties, those with the highest heating values should be selected if competitive in price. All properties of the coal should be considered and evaluated, as coals selected on the basis of heating value alone may be entirely unsuitable for the particular type of equipment being used. When these coals are evaluated in terms of plant efficiency, capacity, and operating cost, it may be found that costs are much higher and operating difficulties much greater. Unless the heating values of the coals that may be appropriately burned are previously considered, the design and size of the stoker selected may impose a low limit on the heating value of the coal that can be burned in the plant if the required amount of steam is generated.

Generated on 2024-09-20 07:36 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

4. FUSIBILITY OF ASH

Probably none of the various coal properties or characteristics, as indicated by the various tests, is as important as the ash-fusion temperatures when selecting coals for underfeed stokers. The ash-softening temperature is a fairly reliable guide to the amount of clinkering that can be expected for a coal, but whenever there is question concerning the coal ash-fusion characteristics due to stoker design or rating, a burning test should be made if many future operating difficulties are to be avoided. Usually, the minimum ash-softening temperature for a free-burning coal can be lower than for a coking coal, owing to a more uniform burning rate. Usually when a coking coal is burned, sections of the stoker may be burning it at a high rate with resultant localized high temperatures, which may cause clinkering of the ash. From an operating standpoint, it is usually necessary to reduce the burning rate and increase the quantity of excess air when clinkering occurs. However, this is done at the expense of capacity and efficiency. Clinkers may adhere tightly to stoker parts and furnace walls, which may be broken when the clinkers are removed and must be repaired at much expense. For equipment designed to burn coal having ash of high fusion temperature, only such coals should be used if operating troubles and increased operating and maintenance costs are to be avoided.

5. ANALYSIS OF ASH

Probably the commonest operating complaint at present concerns the adherence of ash particles to the heat-transfer surfaces of steam generators. More fundamental knowledge concerning the ash constituents of coals and their action when heated may be of value in solving this problem. The use of humidified combustion air with underfeed stokers in winter has proved effective in keeping these ash deposits down to correspond in quantity to deposits in summer when the atmosphere contains greater moisture.

6. FINENESS OF POWDERED COAL; 7. GRINDABILITY; 8. DROP-SHATTER TEST, and 9. TUMBLER TEST

Not applicable.

10. SCREEN ANALYSIS

The size consist of the coal selected for burning on this type of equipment must be considered because size affects burning rate, but chiefly because of the effect of size consist on the coking characteristics of the coal. Whether its effect is serious depends largely on the size and design of stoker and the experience of the fireman or operator. On the large underfeed stoker, change in coking due to size consist is not usually too serious, as compensating stoker adjustments can be made and usually trained and experienced men are on duty. On the small underfeed stoker, however change in size, with resultant change in coking characteristics, may affect stoker performance and fuel-bed conditions very seriously, with resultant loss of capacity and decreased efficiency. Uniformity of coal size consist, as well as other properties, is a decided benefit in the control and efficient operation of the stoker. Coal usually segregates as to size in transportation and handling from mine to stoker. Unless coal-handling equipment and stoker hoppers are designed and operated to reduce this to a minimum, stoker operation is affected, owing to unequal underfire air distribution, which results in very unstable fuel-bed conditions.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL

None.

Generated on 2024-09-20 07:32 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

12. DUSTINESS OF COAL

The dustiness of coal creates a problem when it is unloaded and handled, because the dust is spread around the plant and neighborhood. Feeding dusty coal to the stoker hopper creates a dust nuisance in the plant and a cleaning problem that requires constant attention.

13. FREE-SWELLING INDEX

By a relatively simple test, information concerning the swelling and coking of coals can be obtained that is decidedly useful in selecting coals for burning on underfeed stokers. With a knowledge of the swelling number of various coals, it is possible to eliminate certain coals from consideration and select for trial those from a range that should be suitable for the particular stoker and coal-burning rate required. Time and expense can be saved by reducing the number of trial burning tests. Usually, for the large underfeed stoker with a high burning rate, coals with a high swelling index are most satisfactory and most efficient. Although coals with lower swelling indexes may be burned, more attention by the fireman is required to control the fuel bed, and usually some efficiency is sacrificed. With low swelling-index coals, fuel bed instability may be encountered, and coal may be lifted from sections of the stoker and discharged into the ash pit with high combustible loss, reduced capacity, and decreased efficiency. On the small underfeed stoker, coals in the low and intermediate range of swelling indexes seem generally to be the most satisfactory, because there is less formation of coke masses that may be difficult to break up and burn. The average coal-burning rate to be carried on the stoker will dictate to a great extent the upper limit of swelling index for coals that can be burned satisfactorily. Since coke formation usually is less at high-burning rates, it may be possible to burn coals with higher swelling indexes. When it is necessary to burn a mixture of coals from many mines and seams, better control of the fuel bed and more stable fires can be maintained if coals with about the same swelling index are mixed for burning. Since it is not usually possible to mix coals thoroughly, it is more difficult to control distribution of air through the fuel bed when coals with different coking characteristics are being burned on the stoker simultaneously. Usually, a heavier fuel bed is required for a strongly coking coal than for coal that is more free-burning. If the same thickness is carried where both types of coal are being burned, it is difficult to control air distribution through the fuel bed, as resistance to air flow through the free-burning coal is much greater. As a result, the burning rate on parts of the stoker is exceedingly high, so that the temperature rises to the point where stoker parts are damaged and maintenance costs become excessive. The uncoked particles of the free-burning coal may be blown from the fuel bed either into the ash pit, with high carbon loss, or carried into the gas stream, where the ash may collect on heat-transfer surfaces because the burning carbon keeps the ash plastic and provides a reducing atmosphere with lower ash-fusion temperatures.

14. AGGLUTINATING VALUE

Not applicable.

15. RANK

Coal rank, of course, is a classification of coals based on heating value and chemical and physical properties rather than a test. Knowledge of the characteristics of coals of different rank does constitute the basis for a broad division and selection of coals and realization that certain ranks are entirely unsuitable for burning on this type of equipment. Within individual ranks of coals, however, the variation

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

of coal characteristics and properties must be known if coals are to be selected that will give satisfactory stoker performance at high efficiency.

16. VARIETY

Knowledge of the appearance and composition of different varieties of coal of benefit chiefly in fuel selection, in being able to recognize the coal variety and in a very broad way predict the action that may be expected when the coal is fired on the underfeed stoker.

III. Significance of Laboratory Tests of Bituminous Coal for SPREADER-STOKER FIRING

by J. F. Barkley

1. PROXIMATE ANALYSIS

(a) Moisture. - The moisture determination shows incombustible matter that not only lowers the B.t.u. of a ton of as-received coal but also, as water vapor, carries out the stack latent and sensible heat, thus lowering boiler efficiency. The dew point of the flue gases is raised with increased moisture. This is an important factor in determining the minimum permissible temperature of the outgoing flue gases to avoid corrosion difficulties. Although the moisture analysis is a total of both extraneous and inherent moisture, it can be used as an indication of the "wetness" of the coal, as the user ordinarily knows fairly closely the percentage of inherent moisture of the coal from its coal bed or its rank. Appreciable extraneous moisture causes difficulties in coal handling, such as freezing in cars, increased work to unload, bridging and flow difficulties in downspouts and hoppers, and increased corrosion of coal-handling equipment. It also greatly affects the feeding and spreading of the coal by the stoker. The combustion process itself is affected somewhat.

(b) Volatile matter and fixed carbon. - Although the spreader stoker can handle very satisfactorily any volatile, say, from 10 percent up, knowledge of the volatile is important. Low-volatile coals ignite less readily than high-volatile coals, which causes an increased amount of unburned combustible to be carried out the furnace, reduces suspension burning, and increases burning on the grate. An extreme example of this is shown when anthracite is used. The spreader stoker combustion process practically disappears. Volatile content also affects design of proper furnace. In one series of tests it was found that high-volatile coal, igniting quicker, made less smoke than low-volatile coal, owing to excessive water-cooled surface in the furnace. It was found necessary to cover some of the tubes with refractory to use the low-volatile coal satisfactorily. In general, however, most spreader-stoker installations can use a wide range of volatile.

(c) Ash. - The ash determination shows incombustible matter that not only lowers the B.t.u. of a ton of as-received coal but also points out the ash-handling problem. Although spreader stokers can handle an extremely wide range of ash content, higher ash increases difficulties. Ash accumulates on furnace surfaces, slags, erodes, is carried out of the furnace with the flue gases, coats superheater, boiler tubes, economizer, and air preheater, settles in passes, ducts, and chimney base, and a part goes out the chimney

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

to settle later on surroundings. Higher ash usually causes increased combustible carry-over. Where it is returned to the furnace for reburning, higher ash usually means greater loading on the jet systems and greater erosion difficulties. The time intervals between cleaning fires for stationary or dumping grates depend on the ash content. In one case where an ash of 27 percent was being used, it was necessary to clean every 2 hours. The traveling grate is generally recommended for high ash, especially for the larger boilers. The quantity of ash that comes from the grate plus that which might be added from settlings determines the load that must be placed on whatever ash-removal system is used.

2. ULTIMATE ANALYSIS

The ultimate analysis, with the exception of the sulfur determination, has its chief value in design and in test work where heat balances are made. The hydrogen determination indicates the amount of H_2O that will be added to the flue gases from that source and is of interest at times in general operation. The sulfur determination, however, is constantly desired by coal users. It is an index of the sulfurous gases that get into the flue gases; the greater the quantity, the higher the sulfuric acid dew point. Higher exit temperatures must be used to lessen corrosion, which lowers efficiency. Sulfurous gases leaving the stack form sulfuric acid, an air pollutant that corrodes property and is harmful to vegetation. When equipment is taken out of service, sulfuric-acid corrosion from the sulfur of accumulated deposits becomes very active at the lowered temperature, which permits moisture to accumulate. Sulfur is a very important factor, also, in the formation of a "bonded" type of deposit on equipment, particularly economizers and air preheaters. Sulfur in coal is very frequently associated with iron as iron pyrites and thus can be an index of the amount of iron pyrites in the coal. Since the iron is often the cause of low-ash fusion, operators are likely to expect high-sulfur coals to have low-ash fusions. In the same way, high-sulfur coals are often more subject to spontaneous heating in storage from iron pyrites or "sulfur-balls."

3. CALORIFIC VALUE

This important laboratory test gives the potential heat-producing value of the coal. This affects original design to obtain required loads and also operating possibilities for given equipment. The essential problem of the operator is to transfer as much as possible of this potential heat into heat in the steam. It is a basic factor in comparing coals for purchase.

4. FUSIBILITY OF ASH

The ash-softening temperature is of definite interest to the coal user. It gives much information as to the probable action of the ash.

The spreader stoker handles a very wide range of ash fusion, its comparative freedom from clinker difficulties being an outstanding characteristic. Hence, for many installations operating at ordinary burning rates, particularly the smaller or medium-size ones, not much attention is given the ash-fusion temperature. At higher burning rates, the lower ash-fusion coals may give some difficulties. High ash, together with low fusion, increases difficulties. Where slagging tubes become a factor, as with the larger, high heat-release installations, the ash fusion must be given more consideration as to both design and operation. Little study has been made of the possible use of initial deformation temperature or fluid temperature in connection with spreader stokers as compared to some other types of equipment.

Generated on 2024-09-20 07:38 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

5. ANALYSIS OF ASH

Not used to any extent for spreader stokers. Sometimes the iron content is of interest. There is much to be learned about ash analysis and possible correlations. Studies of the volatile salts in coal in connection with slags and deposits are proving valuable.

6. FINENESS OF POWDERED COAL

Not applicable.

7. GRINDABILITY, 8. DROP-SHATTER TEST, and 9. TUMBLER TEST

Not ordinarily given consideration.

10. SCREEN ANALYSIS

Although a continuously uniform size consist gives better results in spreading, relatively few actual screen analyses tests are made. It is difficult to get a representative sample. Usually there are continual size consist changes in slack coal, which, if of sufficient magnitude, are handled by adjustment of spreader mechanism. For each installation there is, no doubt, an optimum size consist, but this may vary appreciably without major difficulties. There should always be some coarse coal to fall to the grate and enough fines to give good suspension burning. Fines increase dust carry-over. Coarse coal can well be kept no larger than 1-1/4 to 1-1/2 inches. Top-size slack must be determined for each installation and coal purchase.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL

Test not used.

12. DUSTINESS OF COAL

Apparently, operational difficulties from dustiness in bringing coal to stoker have not been great enough to result in much use of this test.

13. FREE-SWELLING INDEX, and 14. AGGLUTINATING VALUE

Not used. No known definite significance of moment. If all other factors were the same, particularly the volatile, it is possible that a coal producing a heavy-swelling coke might give somewhat higher combustible in the dust carry-over than a coal with appreciably lower coking tendencies.

15. RANK

Spreader stokers are satisfactorily burning coals of all ranks, except anthraci

16. VARIETY

Of small significance; can burn all commercial varieties of bituminous and subbituminous coal.

Generated on 2024-09-20 07:32 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

IV. Significance of Laboratory Tests of Bituminous Coal

for

CHAIN-GRATE STOKER FIRING

By A. E. Grunert

1. PROXIMATE ANALYSIS

(a) Moisture. - In chain grate operation, extraneous moisture is essential for efficient burning; practice has indicated that wetting the coal gives a more uniform and porous fuel bed, with resultant increase in the rate of combustion. Excessive moisture affects the efficiency of the steam-generating unit to the extent of the loss of heat by vaporization of excess moisture.

High moisture also may adversely affect the flow of coal in bunkers, spouts, and other conveying devices and, because of freezing, may make unloading difficult.

(b) Volatile matter and fixed carbon. - Utilization of heat from the volatile constituents in coal depends largely on furnace design; sufficient furnace volume is essential to permit thorough mixing of the rapidly liberated gaseous constituents with air for complete combustion. In installations not provided with adequate furnace volume, the percentage of volatile matter in selecting coal is very important.

(c) Ash. - The significance of ash determination is two-fold: it affects the heat value of coal and has a decided bearing on plant efficiency and operation.

The adverse effects of high ash on plant performance and operation are numerous. High ash, even if not fusible, increases the resistance of the fuel bed with reduction in the rate of combustion, entrains particles of carbon (unburned coal) and thus increases ash pit loss, fouls the heating surfaces, and influences operating problems and costs because of the greater quantities of fuel and refuse requiring handling and disposal.

2. ULTIMATE ANALYSIS

The ultimate analysis is used primarily in the calculations of boiler heat balance and has no significance in connection with coal utilization.

(a) Sulfur. - Sulfur is generally considered an undesirable element in coal, and the percentage present is frequently determined independently of ultimate analyses. It occurs mainly in combination with iron as iron pyrites and to a smaller degree as organic sulfur. A small amount of sulfates usually is present, also, chiefly calcium sulfate.

The adverse effects attributed to high sulfur are the corrosive action of the products of oxidation or decomposition of the sulfur compounds on the metallic parts of the equipment with which these products come in contact, the tendency to cause clinker formation in the fuel bed, and the slagging and fouling of furnace walls and heat-absorbing surfaces.

Generated on 2024-09-20 07:31 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

3. CALORIFIC VALUE

The calorific value is of major importance, as it is a measure of the total quantity of energy in the coal.

4. FUSIBILITY OF ASH

Apparently there is considerable disagreement regarding the significance of laboratory ash-softening (fusion) determinations as a measure of forecasting clinkering and slagging on the grates. Ours is a low-fusion coal. However, when burning other than our normal run of coal having appreciably higher softening temperature, there was little correlation between laboratory tests and performance. It is recognized that the atmosphere in which the ash is heated is largely responsible for variations in softening temperatures. The standard method of the Bureau of Mines (and ASTM) recommends a mildly reducing atmosphere in the determination of softening temperature. The probabilities are that this atmosphere does not approximate the complex atmosphere surrounding the ash on the grate. Further investigation to obtain more accurate correlation between the atmosphere surrounding the ash on the grates and that used in laboratory determinations seems desirable.

Ordinarily, only the softening or fusion temperature is considered, but it may be advantageous to take greater cognizance of the initial deformation temperature and the fluid temperature.

The difference between softening (fusion) temperature and fluid temperature may vary considerably, depending on the viscosity of the slag. A slag may be completely melted and yet not flow readily, owing to its high viscosity. It would appear that viscosity, which is admittedly difficult of determination, along with softening temperature is needed for determining clinkering characteristics.

5. ANALYSIS OF ASH

Efforts have been made to establish a relationship between ash analysis and ash-softening temperature. Several methods have been developed for calculating ash-softening temperature from ash analysis.

In our laboratory, analyses have been made of the furnace ash clinkers and the fused ash after the laboratory determination of the softening temperature in an attempt to correlate the boiler furnace atmosphere with the atmosphere used in the laboratory tests. This presumably was the basis upon which the Bureau of Mines concluded that a 50-50 hydrogen and water-vapor atmosphere closely approximated furnace atmosphere. It was found that this atmosphere favored the formation of slag containing iron principally in the ferrous state, the same as found in the furnace clinkers.

6. FINENESS OF POWDERED COAL, and 7. GRINDABILITY

Not applicable.

8. DROP-SHATTER TEST

This test simulates the conditions of handling in the ordinary preparation and transportation of lump coal.

9. TUMBLER TEST

This test simulates rough handling, such as in mechanical conveyors, feed devices, and crushers.

Generated on 2024-09-20 07:38 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The use of both tests is advocated as an index of degradation of coal in handling. In our plants we burn Central Illinois coal almost exclusively, the friable characteristics of which are known, and, therefore, these tests are of no significance to us. In plants that depend on the open market for their coal, these tests may be of value.

10. SCREEN ANALYSIS

The size of the coal has a definite relationship to boiler performance. Too fine coal restricts the flow of air and prevents complete combustion; too large sizes will not hold ignition. There is an optimum size or combustion of sizes for maximum efficiency for individual installations.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL

Except possibly for estimating the approximate tonnage in a storage pile, this determination is of no significance.

12. DUSTINESS OF COAL

Where the coal used is large, there usually is little or no difficulty because of dustiness. When the coal used contains considerable fines or is excessively friable, especially if used in plants in populated sections, the dust produced by its unloading and handling may become a public nuisance. In such cases the dustiness test may be of value.

13. FREE-SWELLING INDEX

A high-swelling coal may be undesirable on a grate where there is little or no agitation. Do not use.

14. AGGLUTINATING VALUE

Do not use.

15. RANK

For our purpose and from an operating standpoint, this classification has little or no value.

16. VARIETY

In our case, these designations are of no particular significance.

V. Significance of Laboratory Tests of Bituminous Coal

for

SIDE-DUMP COMMERCIAL AND INDUSTRIAL UNDERFEED STOKER FIRING

by Douglas Henderson

The side-dump stoker is fundamentally a fuel-feeding mechanism for delivering coal from the exterior of a furnace to the interior, usually by means of rams and pusher rods. To become a satisfactory piece of combustion equipment, however, it is necessary for the introduced fuel to be distributed over the grate sections through which air is supplied by forced draft.

Generated on 2024-09-20 07:32 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

This presents a problem in mechanics, namely, the movement of coal at right angles to the direction of initial thrust. This will carry the fuel bed towards the side dumps, and the timing must be such that combustion must be partly completed before that destination has been reached.

The lateral movement of the coal bed from the retort depends on the degree of grate-bar agitation provided. Individual manufacturers of this type of stoker have used considerable ingenuity in developing their product to accomplish this. Some, on the other hand, have been content to depend on gravity to move the coal from a high spot in the retort to the dead plates.

Just how this is done has a bearing on the coal characteristics that must be considered to insure successful performance of the equipment.

1. PROXIMATE ANALYSIS

(a) Moisture. - No one wants to pay coal prices for water, so the minimum moisture is desirable. Factors beyond the buyer's control tend to increase the moisture content of coal, so it is important to make the determination and effect necessary adjustments. Too much moisture will lead to coal-handling troubles, depending on the mechanical system employed. When the extraneous moisture exceeds 6 percent, difficulties apparently begin.

(b) Volatile matter and fixed carbon. - For these stokers, the volatile content should preferably be restricted to the range 27 to 38 percent. In general, the higher the volatile, the harder is the coal structure; hence, the size distribution is better, with minimum fines in nut-slack and slack sizes. With a reasonable ash content, as the volatile matter increases, the fixed carbon will diminish. This is an advantage for this type of stoker, because it means less solid matter to be distributed over the grates.

(c) Ash. - The ash content should be as low as market economics permit.

2. ULTIMATE ANALYSIS

None. This only becomes important if the performance of the unit is to be stated in heat balance form and it is necessary to calculate the dry and the wet gas losses.

3. CALORIFIC VALUE

None, other than the distinct advantage in obtaining as many heat units in a ton of coal as is economically possible.

4. FUSIBILITY OF ASH

This determination becomes important in those cases in which high-combustion rates result from undersized grate areas or in which the boilers are forced to excessive ratings. High-combustion rates produce high furnace temperatures and hence require coals having a high ash-softening temperature. If coals with an ash-softening temperature low in the range (2,200°-2,500° F.) can be burned successfully, the consumer has a much wider field of selection. These coals are found chiefly in the volatile range mentioned under item 1.

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

5. ANALYSIS OF ASH, 6. FINENESS OF POWDERED COAL, 7. GRINDABILITY, 8. DROP-SHATTER TEST, and 9. TUMBLER TEST

Not applicable.

10. SCREEN ANALYSIS

It has been our experience that these stokers perform best when using a double-screened coal of the pea size. This eliminates the fines and definitely aids the stoker to distribute the fuel uniformly over the grate sections. Coals thus prepared fall into the volatile range mentioned in item 1.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL, and 12. DUSTINESS OF COAL

Not applicable.

13. FREE-SWELLING INDEX, and 14. AGGLUTINATING VALUE

It is our opinion that the present development of these tests offers little of value to the consumer because of their complexity of interpretation.

15. RANK, and 16. VARIETY

Not applicable.

VI. Significance of Laboratory Tests of Bituminous Coal for LOCOMOTIVE FIRING

by E. D. Benton

In practice, a number of the laboratory tests of coal are used to determine the acceptability and to predict the probable performance of coal in locomotives. However, cutting across all technical considerations that affect the acceptability of coal for either on-line or off-line purchases is the matter of relative delivered cost per ton and purchasing policies governed by traffic reasons. The significance of the laboratory tests of coal for locomotive use will differ from stationary practice because of (1) the rigid relation between air supply for combustion and boiler output; (2) the high firing rates; (3) space limitations causing high heat release and low ratio of combustion volume to firebox cooling surface; (4) limited facilities for unloading and bunker storage capacity.

1. PROXIMATE ANALYSIS

(a) Moisture. - Although moisture, as reported in the proximate analysis, occurs in two forms, (1) extraneous or surface moisture and (2) inherent moisture, which is not external and does not wet the coal, it is common practice for both the purchasing and mechanical or operating departments to evaluate the significance of the reported moisture in terms of surface moisture. Surface moisture is related to unloading difficulties at coaling stations in freezing weather and to tender capacity in mild weather owing to the more nearly 90-degree angle of repose when using run-of-mine coal.

Generated on 2024-09-20 07:37 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Frozen coal is a particular handicap to railroads, because yard arrangements usually limit the space that can be provided for unloading facilities and bunker storage capacity, which are often called upon to handle large quantities of coal in short periods, thus making unloading difficulties serious and costly.

In mild weather, excessive surface moisture combined with the fine sizes in run-of-mine coal may cause train delays owing to irregularity of coal supply to the conveyor trough. The inherent spreader-stoker characteristic of close relationship between coal supply and boiler output and the inadvisability of the fireman to leave his seat box under certain road conditions to trim coal conspire to lower maximum output, thus being directly responsible for interference with operating schedules.

Surface moisture is less serious in hand-fired locomotives because they are used principally in switching and branch-line passenger and freight service where operating schedules are usually less exacting than for stoker-fired locomotives in main-line freight and passenger service.

(b) Volatile matter and fixed carbon. - With probably few exceptions, percentages of volatile or fixed carbon have little or no effect upon locomotive performance. The amount of volatile is an approximate measure of the smoke-producing tendencies of coal, and low-volatile coal is used in certain terminals to control smoke in both switching and transfer service and on road engines for building and maintaining fires while in smoke-restriction territories.

(c) Ash. - With the possible exception of size consist, percent of ash is the most significant of the laboratory tests of coal that relate to locomotive fuel performance. Of all the other constituents or properties of coal, ash has the greatest affect upon availability, the principal measure of locomotive performance.

Because of space limitations, grate area and ash-pan capacities are small and the percentage of ash in the coal limits the distance or time a locomotive can remain in revenue service before its fires and ash pan must be cleaned. As a practical matter, the distance between terminals and the number of locomotives required are usually influenced by the percentage of ash in the coals normally available to the railroad. If locomotives are to be operated over more than one division, coals of lower than normal ash content are required or special fire-cleaning facilities must be provided. On the other hand, very low-ash coals often fail to give improvement in fuel performance commensurate with their higher quality.

By and large, coal containing ash in amounts greater than 10 percent on a dry basis necessitates frequent cleaning of fires and ash pans; when the ash content is less than 5 percent on a dry basis, improvement in fuel performance is negligible.

2. ULTIMATE ANALYSIS

The ultimate analysis of coal gives its chemical composition in percentages of ash, sulfur, carbon, hydrogen, nitrogen, and oxygen which are needed for combustion calculations and for calculating heat balances of boiler tests, but is of little or no value in indicating the probable behavior of coal on the grate.

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

3. CALORIFIC VALUE

The B.t.u. value, as reported in the proximate analysis on the "as-received" or "dry basis," is useful only in determining the quality of the fuel, as it reflects the quantity of dilutents, ash, and moisture the coal contains. The heat value does not limit maximum capacity but may limit the length of time maximum output can be sustained or the distance the locomotive can operate. The unit or moisture- and ash-free B.t.u. value is useful to (1) check analysis for possible error in the amounts of moisture and ash reported or the as-received B.t.u. value and (2) estimate within reasonable limits the B.t.u. value when only the moisture and ash are determined.

In the case of off-line purchases, differences in B.t.u. value sufficient to be noticeable in the performance of coal make the higher-quality coal preferable unless traffic or other reasons more than offset whatever differences may exist between coals within a given freight-origin group. In a narrower sense, this applies to coal purchased on line, as f.o.b. mine price will often more than compensate for differences in quality. However, where schedules are critical, particularly in fast-freight and passenger service, quality is often more important than all other considerations.

4. FUSIBILITY OF ASH

Because of thin fuel beds and the large ratio of water-cooled surface to furnace volume, locomotives are reliably operated at high burning rates (100 lb. coal per sq. ft. per hr. and above), coal having a range of ash-softening temperature from 1,900° F. to 3,000° F. There are, however, notable exceptions to this broad generalization, particularly in the low and medium fusion-temperature range, as ash-softening temperature per se is not a definite index to clinker trouble or slagging difficulties. Percent of iron oxide, percent of ash as it influences thickness of ash upon the grate, combustion-chamber length, and type of service performed by the locomotive all modify the relations of ash-softening temperature to clinker or tube slagging difficulties.

5. ANALYSIS OF ASH

The composition of ash has been found useful in explaining the difference in clinker and tube slagging tendencies for ashes having essentially the same softening temperature. The percentage of ferric oxide (Fe_2O_3) in the ash has been found to be a reliable but not necessarily an infallible indicator of clinker and slagging characteristics.

In general, both standing and road tests have shown that when the percentage of ferric oxide in the ash exceeds 32 percent, severe difficulties are encountered. As the percentage of ferric oxide decreases, it has been observed that the severity of these difficulties decreases correspondingly, until no clinkering or honeycombing occurred when the amount of ferric oxide was less than 16 percent.

6. FINENESS OF POWDERED COAL

Not applicable.

7. GRINDABILITY

The grindability of coal is concerned only with pulverized-coal firing and for this reason has no significance for locomotive coal. If the coal-fired gas-turbine locomotive becomes an accepted form of motive power, grindability will become significant, as it is related to pulverizer capacity and cost of pulverization.

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

8. DROP-SHATTER TEST, and 9. TUMBLER TEST

The object of the drop-shatter test and the tumbler test is to provide an index that will establish the relative difference between coals to withstand breakage in handling and size degradation by the stoker feed or conveyor screw.

In the past, railroads in general have given little or no attention to stability or friability of coal because of the lack of reliable data that would indicate the significance of the differences in friability between coals and locomotive performance The significance of these laboratory tests for locomotive coal may change in the future as the use of double-screened coal becomes more general or the use of Diesel locomotive displace coal, thus permitting railroads to be more selective in the purchase of coal.

10. SCREEN ANALYSIS

Variations in the percentage of sizes smaller than.3/4 or 1/2 inch is of greater significance to over-all locomotive efficiency than corresponding variations in any or all of the other physical and chemical characteristics. Variations in such inherent coal characteristics as percentage of moisture, ash, volatile, and calorific value will not usually affect fuel efficiency sufficiently to be measurable in standing or dynomometer tests. There is, however, a definite relationship between unburned-fuel loss and size consist. Except at low firing rates (below 75 lb./sq. ft./hr.) unburned fuel loss is usually greater than the loss due to sensible heat in the smokebox gases. At high firing rates (above 125 lb./sq. ft./hr.), often the unburned-fuel loss is more than twice the sensible heat loss.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL

The difference in bulk density between coal sizes or between coals from different beds is not great enough to affect its acceptability for railroad use.

12. DUSTINESS OF COAL

Although the dustiness of coal can be serious, particularly at coaling stations in residential areas or near passenger stations, tests to establish the relative dust index of coals have not been used as a measure of acceptability or the basis for a request of producers to provide dust treatment at the mines. However, some railroads have used wetting agents for dust control while loading bunkers at coaling stations or locomotive tenders.

13. FREE-SWELLING INDEX

The free-swelling index has been used extensively by several railroads as a means of evaluating and identifying "crop" coal from open-pit mines or coal having insufficient overburden to protect it from excessive seepage and oxidation. As the free-swelling index varies over wide limits between coals, and as coals of equally wide range of quality and rank are used in locomotives, it follows that there is no optimum free-swelling index that may be used as a measure of acceptability except when comparing coal from the same bed.

The usual procedure is to establish, first, the normal bed swelling index of samples taken from the third or fourth cut at a place where the overburden is sufficient to protect the coal from excessive seepage and oxidation; then, by comparison with the swelling index of samples taken at or near the crop line, the degree of oxidation or proximity to the crop line will be established.

Generated on 2024-09-20 08:56 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The free-swelling index of crop coal or coal having inadequate overburden is always less than for coal from the same bed where the roof is impervious; but it does not follow that a lower than normal swelling index indicates unacceptable coal for locomotives. Experience indicates, however, that when there is a marked difference from the normal bed free-swelling index, the coal is usually unacceptable because of inferior quality and structure.

14. AGGLUTINATING VALUE

The agglutinating value is a measure of the caking or coking characteristics of coal, but has not been used by the railroads as a means of establishing acceptability because the spreader-stoker method of firing coal is largely insensitive to the caking tendencies of coal, and the tests for this property of coal have not been sufficiently well correlated with performance in burning fuel beds to be of practical value.

15. RANK

The classification of coals by rank is of general interest and is useful in abbreviating the physical and chemical properties of coal when cataloging or listing a large number of mines that produce a wide variety of coals.

16. VARIETY

Not applicable.

VII. Significance of Laboratory Tests of Bituminous Coal for HAND FIRING

by Carroll F. Hardy

Hand firing of coal is confined to small industrial-power boilers, small heating plants, and domestic furnaces and stoves. The small power boilers include such special uses as cranes, road rollers, dryers, and other movable or temporary equipment. Selection of coal for such equipment is generally given less attention than for larger equipment, and satisfactory operation depends almost entirely on the skill of the fireman.

Hand firing is less scientific than automatic firing, and laboratory tests are likely to be given less consideration by the buyer and user of hand-fired coal. However, careful study of these data will give valuable information about coal for hand-firing.

1. PROXIMATE ANALYSIS

(a) Moisture. - Moisture has little significance in most hand-fired installations except insofar as it reduces the amount of heat available in the coal. The practice of tempering or wetting the coal prior to firing in industrial boilers is quite widespread even when the larger sizes of hand-fired coal are used. This may or may not have a beneficial effect upon firing. In the sizes used for hand firing, excess moisture will drain off to the extent that no handling problem exists.

Generated on 2024-09-20 07:30 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(b) Volatile matter and fixed carbon. - The amount of volatile matter and its relationship to fixed carbon indicates the ease of ignition and rate of burning. Low-volatile, i. e. under 20 percent, coal is slower to ignite and tends to coke and cake more than the medium- and high-volatile coals. Medium- and high-volatile coals, on the other hand, require more care in firing to avoid quick release of the volatiles and consequent smoke. The type of hydrocarbon that constitutes the volatile and the rate of release have a greater bearing on the amount of smoke made than the actual percentage of volatile. Recent tests by the Smoke Abatement Department of the City of Detroit have shown definite lack of correlation between volatile content and smoke emission. Further investigation is needed to establish the exact relationship.

(c) Ash. - Ash as an inert is undesirable, but it serves a useful purpose in protecting the grates. The laboratory test indicates the amount that will have to be handled in excess of the 2 to 4 percent necessary for grate protection. In hand-fired plants, ash usually is removed from the grates or ash pit by hand and wheeled or carried out of the plant. This work usually is a part of the fireman's job in all but the larger hand-fired plants. Generally, the coals preferred for hand firing in industrial plants are low in ash. Firm structure and free-burning characteristics are more important than ash content in home and small heating plants.

2. ULTIMATE ANALYSIS

(a) Carbon, hydrogen, and oxygen. - The ultimate analysis does not differentiate between the various hydrocarbon compounds in coal. The percentages of hydrogen and oxygen may indicate to some extent the burning characteristics of the coal. Coals high in oxygen tend to burn freely and form less coke or "cake" in the fuel bed.

(b) Sulfur. - High sulfur is usually associated with less ash-fusion point. Sulfuric acid may be formed from the sulfur to corrode the breeching and stack. Sulfur compounds give off unpleasant odors in the stack gases or in hot ashes or clinkers. The standards for an unsuitable percentage of sulfur in hand-fired coal vary according to the ready availability of low-sulfur coals. Over 1-1/2 percent sulfur is considered undesirable in some markets, whereas 2 or even 3 percent is low for others.

3. CALORIFIC VALUE

The calorific value of coal or the amount of heat it furnishes for power, proces or space heating is not as likely to be considered the most important factor in selec ing coal for hand firing as it is for automatic firing. Although the average user pr fers low-volatile or high-volatile "A"-grade coal because it is high in heating value a hard-structured cubical-shaped coal is rated higher than a softer or "slab"-shaped coal of a somewhat higher heating value.

4. FUSIBILITY OF ASH

Ash fusion measures the clinkering or slagging tendency of a coal and is of greatest importance in heavy, industrial, hand-fired boilers or overloaded heating installations. Ash-softening temperatures of plus 2,300° F. are preferred and are usually found in the coals selected for other reasons, particularly in the small commercial and domestic field.

Generated on 2024-09-20 07:32 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

5. ANALYSIS OF ASH

The composition of the ash, except those sulfur compounds that release odors, is unimportant in hand firing.

6. FINENESS OF POWDERED COAL, and 7. GRINDABILITY

Not applicable.

8. DROP-SHATTER TEST, and 9. TUMBLER TEST

The friability of coal and its size stability are of great importance in the hand-fired sizes.

The Premium block coals of high-volatile eastern Kentucky, Tennessee, and Virginia are so rated because of their large cubical fracture, regular shape, and ability to withstand rough handling without degradation. The chunk, egg, and nut sizes, which show least degradation, always are rated higher than softer structured coals. Even in the low- and medium-volatile coals, where a highly friable coal is expected, harder structure is an advantage.

10. SCREEN ANALYSIS

Users of high-volatile coal expect a uniform size consist for hand firing. The screen analysis of the sizes down to 2 inches may be a measure of mining or preparation practiced rather than of the coals' fracturing properties. The size consist should be maintained as uniformly as possible to insure use satisfaction. Uniform size consist is harder to maintain in low-volatile coals because of their soft structure.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL

Not applicable.

12. DUSTINESS OF COAL

Dust is of great importance to the user of hand-fired coal. The dust on the block or double-screened sizes of coal for hand firing come from 3 sources: Degradation, particularily from fusain or rash, dried fines or slurry from the washing process, and dust from the type which lodges on the coal.

The dustiness index might be some measure of such dust by reference.

13. FREE-SWELLING INDEX, and 14. AGGLUTINATING VALUE

The free-swelling index measures the free expansion of finely ground coal. Coal in lumps does not follow the same expansion pattern, although there is some correlation. The agglutinating value indicates the type of coke. Some methods of firing, particularly the "coking" method, are designed to make coke by gradual release of the volatile matter. By any method of hand firing, bituminous coal will form a certain amount of coke. "Matting" of the fuel bed is not usually a problem, owing to the method of firing. The fireman either creates coke by firing large quantities of coal at a time, as, for example, with a "side bank," or by firing "light and often" he maintains a thin active fuel bed.

The free-swelling index and the agglutinating value would be of little aid in coal selection unless firing conditions were known.

Generated on 2024-09-20 07:39 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

15. RANK

The rank of coal is important, in that the low- and medium-volatile and high-volatile "A" are preferred, owing to their low ash, low sulfur, and high heating value. The selection between two high-volatile "A" coals, for example, involves laboratory tests.

16. VARIETY

Cannel is considered especially suitable for the open grate or fireplace because of the way it burns.

Most coals used for hand firing are banded and are composed of bright and splint coals. Almost every percentage is represented, from essentially pure splint to half splint and half bright to a high percentage of bright. The "splint" coals (i.e. those largely splint) are favored in high-volatile coals, whereas low-volatile coals are generally bright.

VIII. Significance of Laboratory Tests of Bituminous Coal for RESIDENTIAL STOKER FIRING

by Harlan W. Nelson

The standard laboratory tests, which have proved so helpful in evaluating coals for larger units, can also be used to good effect in the selection and relative evaluation of residential stoker coals. As yet, however, not enough experimental work has been done to permit direct evaluation of stoker coals on the basis of data from standard laboratory tests and analyses. Attempts to do this are handicapped by lack of a standard test set-up and procedure.

The discussion that follows applies chiefly to the use of coal in stokers of the clinkering type, which comprise the great majority of stokers in residential use. Fuel requirements for ash-removal stokers are somewhat different, and these differences are indicated in connection with those tests for which information is available

1. PROXIMATE ANALYSIS

Information supplied by the proximate analysis furnishes only a preliminary indication of the suitability of a coal for use in residential stokers.

(a) Moisture. - Moisture is not a significant factor in judging the relative performance of residential stoker coals. It is of interest principally because of the need for control during sampling and determinations of calorific values for comparative purposes. Variations in surface moisture will affect the size range of coal during preparation at the tipple and will affect the burning properties of coal. Ordinarily, however, the coal delivered to the retort of a residential stoker does not contain excessive surface moisture, and evaluative performance tests ordinarily are made with coal containing little surface moisture.

(b) Volatile matter and fixed carbon. - The percentage of volatile matter has been found by Boley and Helfinstine to have no relation to the performance characteristics of coal, such as the responsiveness of the fuel bed or combustion efficiency. Although the volatile-matter content usually is considered an indication of smoke-producing tendencies during combustion, the

Generated on 2024-09-20 07:42 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

burning of coal in residential underfeed stokers is essentially smokeless during heat-demand operation. Only immediately after the stoker shuts off is there a tendency for smoke to be emitted. R. A. Sherman has shown that the degree of smoke emission is not directly related to the volatile content, as there are great differences in the concentration of smoke produced with different coals of similar volatile content. The percentage of fixed carbon is not significant in judging residential stoker coals.

(c) Ash. - The percentage of ash is a significant criterion in evaluating stoker coals, in that high-ash coals involve additional work in handling the clinkered refuse, and the calorific value varies in proportion to the ash content. In addition, for a given coal, a reduction in the percentage of ash has been noted to result in improvement in performance characteristics. If other conditions are equal, the amount of fly ash produced becomes greater as the percentage of ash is increased.

2. ULTIMATE ANALYSIS

The ultimate analysis is seldom used in evaluating coals for use in residential stokers, except for the determinations of sulfur and ash. The percentages and chemical combination of the carbon, hydrogen, and oxygen in a coal are related to other characteristics, such as calorific value and coking properties, but no data are available relating these determinations directly to observed performance characteristics.

Although no direct evaluation can be placed upon the percentage of total sulfur, a value of two percent or less is desirable. Values in this range are desirable chiefly for reasons of secondary effects, such as odor of clinkers upon removal from the furnace, suspicion of corrosive action, and atmospheric pollution. Pyritic sulfur is related to clinker formation because of its effect in lowering the ash-softening temperature and in producing a more fluid slag.

3. CALORIFIC VALUE

The calorific or B.t.u. value is the basic measure of the total energy in a coal. The proportion of this energy that can be utilized effectively depends on factors of equipment and operation, but the total energy, as represented by the B.t.u. value, is the primary criterion for purposes of relative evaluation.

For determination of the comparative performance of bituminous coals in a single test set-up, the heat output of the unit bears a fairly close relationship to the calorific value. This relationship can be changed by other characteristics of the coals, particularly by caking or clinkering tendencies. For this reason, the calorific value is not of direct significance in relation to the performance of coals as measured by uniformity of combustion, responsiveness, and hold-fire operation. Many coals of high B.t.u. content are ruled out entirely for use in residential stokers, because other properties prevent their successful utilization.

In tests of a series of bituminous coals of the same rank classification, Helfinstine and Boley reported a slight increase in over-all stoker-boiler efficiency of about 1-1/2 percent for each increase in heating value of 1,000 B.t.u. per lb. They found no relationship between calorific value and other performance factors.

4. FUSIBILITY OF ASH

The ash in the fuel bed of a residential underfeed stoker must be removed manually in the form of clinkers; it is therefore evident that the ash-fusion characteristics are extremely important in determining the use value of a coal. The clinker

Generated on 2024-09-20 07:42 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

must be strong enough to permit its extraction from the fuel bed with clinker tongs; it must not have once been so fluid in the bed as to interfere with the tuyere openings of the retort; and the amount of clinker must represent a satisfactory proportion of the total ash released in the combustion process. A suitable clinker must be formed under both low- and high-rate conditions of operation.

It is known that a number of factors, including the kind and distribution of the mineral materials that contribute to the ash residue, their reactions and melting characteristics under the influence of heat, and the character of the fuel bed are involved in an evaluation of clinker formation. The standard laboratory test commonly used to furnish a measure of clinker-forming characteristics of a coal is the ash-softening temperature, and it is far from being infallible. On the basis of numerous laboratory tests of residential stoker coals, it has been determined that coals having ash-softening temperatures from 2,000° to 2,500° F. generally are suitable for the clinkering-type stoker. Coals with softening temperatures up to 2,700° F. have been used successfully in many installations, but not all of these coals can be used with satisfaction during periods of mild weather.

Attempts to relate the ash-softening temperature to the degree of clinker formation or to measurable performance characteristics of coals subjected to laboratory burning tests have not been successful.

In residential stokers of the ash-removal type, it is evident that the formation of clinkers is to be avoided and that coals having high ash-softening temperatures are desired. Because ash-removal stokers are relatively new, no data as to lower limits of ash-softening temperatures are available.

5. ANALYSIS OF ASH

The ash-softening temperature and the behavior of ash when the temperature is high are fundamentally related to ash composition. The ash-softening temperature is useful as a guide in evaluating coal, but the composition of the ash, which is a more complex function, is used less by fuel engineers. Actually, the ash analysis may be a better guide to the behavior of ash, but until many more data are obtained from controlled burning tests, a definite relationship between ash composition and the formation of clinker in fuel beds cannot be formulated.

At present, knowledge of the ash composition has only a very limited significance in the selection and evaluation of residential stoker coals because of unpredictable conditions of temperature and ash distribution in the fuel bed.

6. FINENESS OF POWDERED COAL, 7. GRINDABILITY, and 8. DROP-SHATTER TEST

No significance.

9. TUMBLER TEST

The friability of bituminous coal, as determined by the tumbler test, is only indirectly related to the performance of coals in residential stokers. It is related to the degradation of coal in mechanical feeding systems such as are used in stokers. It is significant in this regard, because the size consist of the coal actually delivered into the retort is related to performance and burning characteristics.

In a study of the relation of the size of coal in the stoker hopper to that burned in the retort, Sherman, Kaiser, and Limbacher found that the percentage decrease in the top sizes increased with an increase in the friability index. They

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

also found that calculation of a friability index from the amount of crushing of 1-1/2 x 0-inch coals in the stoker and comparison of these values with those obtained from the small-mill method showed a definite relationship between the friability indexes determined by the two methods.

10. SCREEN ANALYSIS

Screen analyses are important criteria in the evaluation of stoker coals, because the performance and burning characteristics of coals are greatly influenced by the size consist of coal delivered to the hopper. In addition, the screen analysis is of further value in this regard, because the monetary realization to the coal producer and the tonnage available are significantly related to the size range of the stoker coal. The practical top size of stoker coal is limited by the dimensions of the feed screw and conveyor tube, the maximum size being 1-1/4 inches for residential units. Because of adverse consumer reactions to the presence of coal fines, and because feed rates, segregation in the retort, and combustion and performance characteristics are affected when coals contain appreciable proportions of fines, stoker coals usually are double-screened.

In all studies of the performance and relative evaluation of residential-stoker coals, the screen analysis furnishes useful information for control of the tests and interpretation of results.

11. WEIGHT PER CUBIC FOOT OF CRUSHED COAL

Determinations of bulk density are significant, in that they are related to the rate of coal feed to the retort of a stoker and therefore to the capacity of the stoker in terms of heat release. The bulk density does not furnish an exact relationship as it is affected by moisture content, size, and size distribution, but it is a combined measure of these factors and useful for that reason. If the bulk density of coal in the hopper changes appreciably, the air setting may be incorrect, and the combustion performance of the coal is changed accordingly.

12. DUSTINESS OF COAL

The consumer of residential-stoker coal desires a clean coal in the sense that a minimum of dust is raised during delivery and during the time the hopper is being filled. It is essential that the treatment used for allaying dust be permanent.

The dustiness determination is valuable in determining the amount, type, and permanence of treatment, including methods of application, effect of storage, and response of various coals to treatment.

13. FREE-SWELLING INDEX

The free-swelling index is useful as a preliminary indication of coking tendencies, inasmuch as the extent of coke-tree formation with strongly coking coals is one of the limitations in the use of bituminous coals in the residential underfeed stoker. Excessive coke-tree formations result in deep fuel beds, preferential channeling of air and irregular combustion, slow rate of response to demand for heat, and generally unsatisfactory performance. For these reasons, a direct or relative measurement of coking properties that can be related to fuel-bed performance is highly desirable.

Correlation of the experience gained in laboratory burning tests with the results of determinations of the free-swelling index have shown that coals having an index number of 6 or less will cause no difficulty from excessive coke-tree formations in

Generated on 2024-09-20 07:30 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

the fuel bed of the residential underfeed stoker. Coals with higher indexes of 8 or 9 may or may not cause excessive coke formations, but actual burning tests must determine their suitability.

The relationship between free-swelling indexes and weight of coke remaining in the fuel bed is fairly close, but exceptions are introduced by the inability to maintain constant excess air. Attempts to relate free-swelling indexes with performance factors obtained in laboratory tests have been less successful; there are rather wide variations in such factors as uniformity of combustion and responsiveness among coals having index values of the same order.

The fact remains, however, that the free-swelling determination furnishes a convenient method of appraising the suitability of a coal for use in the residential underfeed stoker, although few such data are available in published literature, and there is need for further information derived from controlled tests.

14. AGGLUTINATING VALUE, and 15. RANK

No significance.

16. VARIETY

It is probable that the performance characteristics are related to the variety of coal used, as such factors as coking properties are involved. Few data are available, but it has been noted that an increase in vitrain was generally accompanied by more uniform combustion in tests of coals of high-volatile B and C rank.

IX. Significance of Laboratory Tests of Anthracite

for

PULVERIZED-COAL FIRING AND FOR TRAVELING- AND CHAIN-GRATE STOKER FIRING

by C. H. Frick

Traveling-grate or chain-grate stokers will be considered as one and the same in this discussion and will hereafter be referred to as stokers or stoker firing. The significance of laboratory tests of coal will apply equally to both.

1. PROXIMATE ANALYSIS

(a) Moisture

(1) Pulverized-Coal Firing. - Owing to the relatively high moisture conten of small anthracite, it is necessary to dry it in the pulverizing proc ess. It is essential to know the moisture content in order to obtain proper equipment. If separate dryers are used to dry coal before it i fed to the mills, the moisture content will govern, in large part, capacity of equipment required to dry a given amount of coal. Wet anthracite may be put directly into the mills, where moisture is reduced to a satisfactory level by passing high-temperature preheated air, pos sibly on the order of 600° to 650° F., through the mill. The capacity of any mill decreases as moisture content of coal increases. Again, knowledge of moisture content is essential in order to determine capacity of mills necessary to grind a given amount of coal. This information is essential also to determine the effect upon performance of a given installation.

Generated on 2024-09-20 07:32 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(2) Stoker Firing. - The moisture content, both extraneous and inherent, of anthracite, particularly of the smaller steam sizes, is a very important factor with respect to combustion of this fuel. It is generally believed that a small amount of moisture in coal, particularly when fired on stokers, is beneficial. When it increases beyond a certain amount, it becomes a detriment, as it slows down the speed of ignition of the coal as it enters the furnace. Therefore, knowledge of moisture content is very essential to the coal user.

Furthermore, this information may enable the user to obtain adjustment in the weight of material he pays for.

(b) Volatile matter and fixed carbon. - The volatile content, on a dry basis, ranges from approximately 3.5 to 10 percent. In actual practice more refractory surface is required in a boiler furnace to maintain good ignition with a low-volatile coal than is necessary with a higher-volatile coal. This applies to both pulverized coal and stoker firing. It is therefore very important to know the volatile content of the coal in order to establish the best arrangement of the furnace refractory material and the shape of the furnace in order to obtain highest thermal economy.

A coal high in fixed carbon and containing little or no volatile matter is relatively difficult to ignite in a furnace, and the use of a great deal of refractory surface is required to burn it.

(c) Ash. - The efficiency of utilization of coal in any furnace varies somewhat with variation of ash content.

If a stoker installation is designed to burn coal containing a moderate amount of ash, such as, say, 12 to 16 percent, and the ash content is too low, the thermal efficiency may be reduced. For a few points above this range, the performance might decrease somewhat, and as the ash content increases further, a point will be reached where the coal becomes practically valueless.

In many cases coal is purchased on a bonus and penalty basis, a fixed ash content (dry basis) being used as a basis for payment, with variations from standard used for adjustment in payment of the coal.

2. ULTIMATE ANALYSIS

Ultimate analysis is customarily not made except in cases where acceptance tests or some other special tests are desired, and from which a heat balance is to be computed. However, an ultimate analysis gives some clue as to whether or not coal has been oxidized by being weathered; that is, coal that has been taken from seams near the surface or from piles that have been exposed to the weather for a number of years. A high oxygen content is indicative of the "weathering" of the coal and, therefore, its suitability for firing, particularly on stokers. If the coal is highly oxidized, it burns with greater difficulty because of the slowness with which oxygen can combine with the combustible portion of the coal particles. Sulfur determination is of rather minor value, because virtually all anthracite has a relatively low sulfur content.

3. CALORIFIC VALUE

Anthracite, in general, on a moisture- and ash-free basis has a rather constant B.t.u. value when the volatile matter is constant. In most cases, volatile matter

Generated on 2024-09-20 07:50 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

has a higher heat value per pound than fixed carbon. Therefore, on any particular anthracite, with a reasonable number of calorimeter determinations of B.t.u. value, a relationship between the volatile matter and B.t.u.'s can be established that will be satisfactory for normal use in computing heat balances. Of course, in acceptance tests or for other special reasons, it may be necessary to make the usual calorimeter B.t.u. determinations.

4. FUSIBILITY OF ASH

The softening temperature is generally indicative of what can be expected from slag formation when the fuel is burned in a furnace.

As stated previously, the lower the volatile content of the coal, the greater must be the refractory covering in the furnace in order to promote proper ignition and burning of the coal. If the fusion temperature of the ash is too low, great difficulty may be experienced with slag and clinker formation, which may seriously reduce the amount of steam obtained from the boiler. For the same volatile content of coal from different areas, such as 8 to 9 percent, the fusion temperature of ash may range from 2,000° to 2,900° F.

The fusion temperature of ash depends largely on the chemical make-up of the ash. However, after a number of fusion determinations have been made on coal from any area, an occasional test will be sufficient to enable plant operators to minimize difficulties due to clinker or slag formation in the furnace.

5. ANALYSIS OF ASH

Normally, determination of the chemical composition of ash does not have much value in burning anthracite. It is generally alkaline in reaction.

If the refuse from any boiler plant is somewhat lumpy, as it is from many stokers, it is suitable for use in manufacturing building blocks.

Generally, phosphorous content is not determined regularly.

6. FINENESS OF POWDERED COAL

Anthracite, being a fuel of low volatile content, should be ground fine for efficient utilization in the boiler furnace. In some cases, thermal performance as well as clinker and slag formation are very sensitive to slight changes in fineness of coal. It is desirable that as much of the coal as possible pass through a 100-mesh sieve, with little or none remaining on top, whereas the percentage through a 200-mesh sieve generally will range from 85 to 90. Accurate screening tests of pulverized anthracite are necessary in order that plant operators may obtain best furnace performance. The screens used for testing must be very accurate and should be tested from time to time as to variations from standard.

7. GRINDABILITY

The grindability of anthracite varies considerably and has some relation to the volatile content of the coal. The lower volatile coal generally has lower grindability, whereas the higher volatile coal has higher grindability, the range being from approximately 30 to 60 percent on the Hardgrove scale. In advanced planning for any pulverized fuel-burning plant it is necessary to know this factor so that grinding equipment of proper capacity would be selected to produce a given amount of pulverized coal. Having established the relationship between volatile matter and grindability of coal from any area, routine checking of volatile content will be a reasonable measure of grindability.

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

8. SCREEN ANALYSIS

In pulverized firing there is a relationship between quantity of finished product from a given mill and size of coal particles entering to maintain constant fineness of output. Variation in capacity is rather small unless the coal has wide range of particle size in its raw state. In general, small coal particles are used for pulverizing because their cost per B.t.u. is less than that of larger sizes.

In stoker firing, it is important that coal particles be uniform in size, whether they be No. 3 buckwheat (barley) or No. 4 buckwheat (these two being the sizes customarily used in stokers). For two coals of the same chemical characteristics, the one of most uniform particle size will produce the best thermal results when burned under similar conditions in a boiler furnace.

9. CLEANLINESS OF ANTHRACITE

Another very important factor in burning either No. 3 or No. 4 buckwheat, particularly the latter, on stokers is cleanliness. A proximate analysis and screening test of these sizes may indicate that they are satisfactory, and yet great difficulty may be experienced in trying to burn the coal. This is largely because a coating of inert material, such as clay or mud, has been deposited on the individual coal particles through use of dirty water in preparing the coal.

In some cases acid mine water that has been neutralized by the addition of lime is used for preparation of coal. A combination of dissolved lime and dirt on the coal produces a bond between particles as the coal dries and results in a "crust" over the surface of the coal in the furnace, which makes penetration of air through fuel bed very difficult. No test has yet been developed to determine the detrimental effect of this combination on combustion efficiency.

X. Significance of Laboratory Tests of Anthracite

for

MEDIUM-SIZED INDUSTRIAL AND RESIDENTIAL-STOKER FIRING

by R. C. Johnson

1. PROXIMATE ANALYSIS

(a) Moisture. - The moisture has a negligible effect upon the combustion of anthracite. However, the feed rate with the various types of conveyors for stokers may vary with the moisture of the fuel. The moisture may influence the rate of corrosion of the conveyors.

(b) Volatile matter and fixed carbon. - Volatile matter influences ignition temperature and ignition rate. Volatile matter is an index of the density of anthracite, and the rate of feed to a stoker varies as the density of the fuel. The higher-volatile anthracite also is subject to greater degradation in some types of underfeed stokers. The degradation increases fly ash, affects air distribution, increases bed resistance, and increases the tendency of the ash to clinker.

(c) Ash. - The ash content influences the calorific value of the fuel and the amount of combustible fed at any given rate of conveyor operation. As the ash content of the fuel varies, a change in feed rate and air is necessary.

Generated on 2024-09-20 07:40 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

In general, as the ash content increases, the carbon content of the refuse of the stoker increases. Ash content also has an influence on the wear of the ash-removal system.

2. ULTIMATE ANALYSIS

Sulfur - none.

3. CALORIFIC VALUE

Covered under other items.

4. FUSIBILITY OF ASH

Ash with fusion points above 2,800 has no effect upon combustion. At intermediate temperatures, clinkering can be overcome by proper adjustment of the air. With a fusion temperature below 2,400 there is a tendency to clinker in the underfeed anthracite stoker, which in certain instances may cause difficulty. The low-fusion ash form clinker and may fuse to the retort, which upsets bed conditions. Clinkering also tend to increase the ashpit losses by entrainment and, in general, increases the stack loss by lowering the CO_2 owing to poor air distribution.

5. ANALYSIS OF ASH

Phosphorous in the ash - none.

6. FINENESS OF POWDERED COAL, and 7. GRINDABILITY

Not applicable.

8. SCREEN ANALYSIS

The use of anthracite of uniform size in industrial and domestic stokers is very important, because the undersize increases bed density, which requires greater air pressure, limits the burning rate, and increases the fly ash and the tendency of the ash to clinker.

9. WEIGHT PER CUBIC FOOT

The cubic-foot weight is important from the standpoint of the amount of fuel fed by the conveyor. The weight of the fuel fed may vary as much as 20 percent when changing from a low-volatile to a high-volatile anthracite because the conveyors feed by volume.

XI. Significance of Laboratory Tests of Anthracite for HAND FIRING

by Allen J. Johnson

1. PROXIMATE ANALYSIS

The proximate analysis of anthracite is of considerable value in determining the value and characteristics of the fuel for hand firing and should be rated "very essential."

Generated on 2024-09-20 07:37 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(a) Moisture. - Both the inherent moisture and the moisture at the time of weighing for retail sale are directly related to the cost of the fuel on a heat-value basis. As anthracite is weighed for local retail sale without allowance for moisture content, each percentage of inherent moisture above the inherent minimum reduces the heat value below that of air-dried coal by the same amount.

In hand-fired combustion, moisture reduces the efficiency, but this is decidedly secondary to the question of its effect upon the purchase value, for two reasons:

(1) Anthracite drains freely in storage (assuming the domestic sizes) and thus, as fired, will probably be considerably closer to an air-dried condition than when delivered. (The shrinkage in weight will, of course, affect the value per pound remaining, but this has been considered in the purchase of wet coal.)

(2) The "house-heating" efficiency, which determines domestic economy, is so high that a slight difference in boiler efficiency is seldom reflected in annual tonnage.

(b) Volatile matter and fixed carbon. - With anthracite, volatile is of importance because it has been shown to be directly related to the specific gravity and also to the burning index of the coal.

The relation to the specific gravity may be used as an indication of the density of the coal (a) for determining the storage space required and volume and (b) for use as an approximation of the burning characteristics. The Anthracite Institute Laboratory, in a series of studies of several coals, showed that about a 10 percent increase in draft was required for dense or high-gravity coals, as compared with lighter or "free-burning" coals. The volatiles of several anthracites are so similar in heat value that, for any given volatile and ash content, the heat value can be closely approximated.

(c) Ash. - The ash content of anthracite affects its value from several angles:

(1) It directly affects the heat value, hence the cost per unit of useful heat.

(2) Excess ash increases the labor of handling and firing the coal.

(3) Excess ash increases the labor, inconvenience, and cost of ash removal.

(4) If excessive, ash often materially affects combustion. In some coals and coal sizes this occurs through insulation of the individual pieces of coal by heavy ash layers, so that the coal does not burn completely to the center; in others it interferes with general combustion conditions in the fuel bed to materially reduce the rate of combustion and heat output; and in a third group it aggravates clinker. Combinations of these difficulties are not uncommon with high-ash coals.

The anthracite industry has adopted standards of ash allowance that should serve as a guide to the dividing line between good and potentially objectionable coal.

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

2. ULTIMATE ANALYSIS

For purposes of hand firing, the ultimate analysis of anthracite would throw very little light on performance expectancy that could not be determined from the proximate analysis.

3. CALORIFIC VALUE

As the B.t.u. content of a coal is the measure of the heat value, and as the only reason for hand-firing coal is to obtain heat, this is of paramount importance.

There is some question as to the advisability of preparing coal beyond a certain undetermined point of perfection because of the protection to the grates afforded by a certain amount of ash. However, with present preparation standards this is more of a concern with such fuels as petroleum coke than with anthracite. In my opinion 6 percent ash is about the safe minimum on this score.

4. FUSIBILITY OF ASH

Several factors determine the clinkering of anthracite in addition to the fusibility of the ash, so that although the fusion point is rightfully regarded as a useful clue in the hands of experienced engineers, it is little more than just that.

Burning rate, of course, is an important point in determining the temperature developed in the furnace. In a field survey of a large number of houses we found absolutely no correlation between the size of the houses and the grate areas. As a result the tons of coal burned per year per square foot of grate ranged from a minimum of 1.9 to a maximum of 10. Obviously, coal with a given fusion point might behave quite differently at the two extremes; these were not exaggerated cases, as there were as many 2 tons per square foot per year as there were 8 and 9 tons.

At the Fifth Lehigh Conference, Schantz lists several causes for clinker, some of which are only vaguely related to the fusion point, others not at all. These include:

1. Insufficient air
2. Unequal distribution of air
3. Excessive drafts or burning rates
4. Agitation of the fuel bed
5. Sudden changes in the combustion rate
6. Excessively thin fuel beds
7. Degradation of coal
8. Presence of fines in the coal
9. Presence of foreign material in the coal
10. Chemical composition of the coal ash
11. Fusion temperature of the coal ash

5. ANALYSIS OF ASH

The same comment would apply, and to the same degree, as in the preceding section

6. FINENESS OF POWDERED COAL, and 7. GRINDABILITY

Not applicable.

8. SCREEN ANALYSIS

Uniformity of sizing is of considerable importance with anthracite, particularly as the sizes become smaller. Excessive degradation reduces the efficiency by an amoun

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

that, at best, wastes the full weight of the fines, increases the likelihood of clinker, and reduces the output.

In mixing coal of different sizes, extreme care must be used to avoid one or more of these faults. Even so, it must further be remembered that laboratory tests do not include the conditions of segregation and consumer faults of firing that will later follow the mixtures to the field. In mixing sizes, only those sizes adjacent on the anthracite-sizing scale should ever be used.

XII. Significance of Laboratory Tests of Coke

for

TRAVELING-AND CHAIN-GRATE STOKER FIRING

by C. H. Sawyer

Both economics and the nature of the combustion process dictate the restriction of coke for use as a chain-grate stoker fuel to sizes below 3/4 inch and usually below 1/2 inch - in other words, the material commonly known as breeze. Undoubtedly its utilization has suffered from an apparently unavoidable tendency to consider it a "waste" or "refuse" product.

Coke breeze is burned occasionally with other fuels, either in intimate mixture or by layering the various fuels through a divided hopper. Fine anthracite, bituminous coal, and pitch have all been used with breeze in such fashion, usually with the claim of improved ignition characteristics. There has also been recent mention of successful experiments with fine sizes of petroleum coke on traveling-grate spreader stokers. However, by far the largest use of breeze is on conventional chain grates.

1. PROXIMATE ANALYSIS

(a) Moisture. - Moisture undoubtedly affects the ignition characteristics of the fuel, although there is a tendency among boiler-house men to disregard moisture variation within rather wide limits. Its routine determination is important, as it is a diluent to be considered in purchasing and, of course, it robs the boiler of its latent and sensible heat in its exit as a vapor in the stack gas. Only total moisture is determined, as all moisture present in coke may be considered as "extraneous moisture."

(b) Volatile matter and fixed carbon. - These factors appear to have little significance for the subject application. Apparently, in the range commonly encountered (1.5 to 2.5 percent), any effect of volatile matter upon ignition characteristics is negligible. The fixed carbon may be useful, together with other information from the proximate analysis, for approximate calculation of efficiency.

(c) Ash. - Ash is the most important single factor in the general concept of fuel quality. It is imperative data for purchasing or in any assay of plant performance, whether by long-term record or controlled heat-balance experiment.

2. ULTIMATE ANALYSIS

Seldom determined for breeze but would be a factor in making a rigid heat balance involving net heating value, etc.

4402

Generated on 2024-09-20 07:41 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(a) Sulfur. - Sulfur may be of considerable importance for its bearing on corrosiveness of flue gases and, in a few cases, because of its part in atmospheric pollution. However, there is commonly much less sulfur in coke or breeze than in the coals usually applied to chain grates, and ordinarily it is not determined.

3. CALORIFIC VALUE

Necessary for rigid heat-balance work, but with this extremely low-volatile fuel a heating value calculation, even on the basis of the proximate analysis, can yield sufficiently accurate information for most purposes.

4. FUSIBILITY OF ASH

This is a factor of no significance in chain-grate stokers, as even very low-fusing ash gives no trouble in the practically undisturbed fuel beds involved. Furthermore, present coke-plant practice keeps ash fusion above the trouble range, even in equipment requiring higher ash-fusion temperatures than the chain-grate.

5. ANALYSIS OF ASH

There appears no present use for this test in connection with the subject application.

6. VOLUME OF CELL SPACE OF LUMP COKE, 7. DROP-SHATTER TEST, and 8. TUMBLER TEST

Not applicable.

9. SIEVE ANALYSIS

This is by far the most important single A.S.T.M. test to chain-grate users, as so many factors vital to operation depend on fuel size.

Sizes much above 3/8 inch and certainly above 1/2 inch are likely to carry over with discharging ash, unsatisfactorily burned. Worse, if any appreciable proportion of the larger sizes is present, difficulty in maintaining general ignition arises.

It is common practice to operate modern chain-grate stokers burning coke breeze (in double-arch settings) in such a way that the blast in one or two boxes adjacent to the "burning out" zone under the rear arch carries a shower of incandescent coke particles back onto the incoming fuel as an aid in ignition. Owing to the classifying effect of such blasting, size consist determines the amount and distribution of the igniting shower so obtainable.

The proportion of very fine material largely determines the extent of siftings, flue-dust accumulation, and draft requirements, although the use of forced draft has somewhat reduced the importance of size consist from the last standpoint.

No "best size consist" can be specified. In the words of one plant manager, "you burn what you've got!" However, a fair proportion of "fines" seems necessary for good ignition. In a recent limited survey of actual coke-plant practice such "fines" content varied from 35 percent to over 50 percent through 1/8-inch square-mesh screen. In this connection, the experience of one operator is of interest. He reported elimination of ignition difficulties in the power plant every time the coke plant's general operations included crushing. No explanation was offered. Possibly, crushing augments breeze output with a flakier fine material, which ignites more easily than does the naturally produced breeze. None of the tests herein considered would be likely to show such a difference in product.

Generated on 2024-09-20 07:32 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

10. WEIGHT PER CUBIC FOOT

Important in connection with storage requirements or stock estimates. The extreme variability of breeze moisture would introduce difficulty here and should be considered carefully in using any such data.

11. DUSTINESS OF COKE

Dustiness testing has no real application in this connection, as such use is completely industrial, and no provision for adequately dust-proofing such a material would be economically feasible.

XIII. Significance of Laboratory Tests of Coke

for

DOMESTIC STOKERS AND HAND FIRING

by C. E. Shaffer

There are few coke stokers in use in the United States, and those that have been developed generally use approximately the same domestic sizes used in hand firing. This is in contrast to coal stokers, which usually require special stoker sizes. For this reason, the characteristics of coke required for stoker fuel are approximately the same as for hand-fired fuel. Except when noted, therefore, the following discussion applies to both stoker- and hand-fired cokes.

Also, this discussion relates only to high-temperature byproduct coke, which comprises by far the greatest percentage of domestic coke used in this country. The significance of tests on low- or mid-temperature coke may be different in some instances but will not be dealt with here.

In preparing this paper, the significance of tests to the domestic consumer has been kept in mind, as well as the significance to the producer. The average consumer has never heard of the tests, but in reality he is the one to whom they are most significant.

1. PROXIMATE ANALYSIS

(a) Moisture. - High-temperature coke contains no inherent moisture, and so the term "moisture" may be taken to mean only extraneous moisture. The moisture test obviously is significant because, as with any fuel, moisture decreases the heating value of the fuel as received and therefore lowers its intrinsic value.

Moisture also may affect the cleanliness of coke. Fine coke dust produced in storage or in handling tends to stick to damp or wet coke and later to create a dust and dirt nuisance in the customer's home after the coke has dried out in his bin. Dust treatment is rendered partly ineffective by the damp coating of dust, and a larger quantity of dust-treating agent is required to obtain the desired cleanliness.

(b) Volatile matter and fixed carbon. - Volatile matter generally amounts to between 0.5 and 1.5 percent and in some instances may have a slight significance as to the combustibility of the coke. However, many cokes of the same volatile content may have considerably different combustibilities, and the volatile matter cannot be used safely as an index. It has little

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

other significance to the consumer. Fixed carbon on a dry basis by definiti is equal to 100 percent-percent V. M.-percent Ash. As the percentage of vol tile matter in most high-temperature cokes is low (averaging about 1 percent the fixed carbon is largely determined by the ash content. Fixed carbon is what the customer burns to obtain heat, and so the test is highly significan

(c) Ash. - Ash, as shown above, largely determines fixed carbon and therefore is highly significant in determining the value of the coke.

Ash must be disposed of and, obviously, cokes of higher ash content create more of a disposal nuisance and, in some instances, a higher disposal cost than cokes of low-ash content. No actual conclusive data are at hand, but from experience and observation it seems probable that higher ash results in increased fly-ash production, with attendant lower boiler efficiencies. High-ash coke is also believed to cause more clinkers than low-ash coke, both having the same ash-fusion temperature. Finally, the higher-ash coke requires that more attention be paid to the fire, as more frequent shaking is necessary. All in all, the ash test is of especial significance to the domestic coke user.

2. ULTIMATE ANALYSIS

No significance except sulfur.

The sulfur content is often, though not always, indicative of the ash-fusion temperature. Excessive sulfur also is conducive to corrosion of stove pipes, stoker limit controls placed therein, and to chimney corrosion. Sulfur dioxide odors, sometimes obtained when opening the fire door, are obnoxious and damaging.

3. CALORIFIC VALUE

The B.t.u. test is considered as superfluous and is little used by domestic coke producers. It is true that the calorific value is of utmost importance to the consumer. However, the B.t.u. can be estimated from the fixed carbon content, which, for practical purposes, may be considered to be pure carbon.

4. FUSIBILITY OF ASH

Generally speaking, the ash fusion test denotes the tendency to clinker formation but there are puzzling exceptions. Considerable effort has been made by several investigators to correlate initial deformation temperature, softening temperature, and fluid temperature with clinker formation, but no fool-proof index is known to the writer. The softening temperature is most often used and, with exceptions, may be considered to be a fair index.

5. ANALYSIS OF ASH

No practical significance to the domestic consumer.

6. VOLUME OF CELL SPACE OF LUMP COKE

No practical significance as such. However, porosity is calculated from the true and apparent specific gravities. Of these, the apparent gravity has significance, as it determines the volume per unit weight, size and shape factors not considered. This in turn, affects the size of truck bodies and the amount of coke that can be stoked into a furnace. Claims that porosity in itself affects combustibility are not substantiated, for cokes of low combustibility and high porosity are known, and vice versa.

7. DROP-SHATTER TEST

Little practical significance, except as an indication of the constancy of oven-coke quality. To the producer, the shatter-test index (percentage on 2 inch) may have some significance. High indexes may indicate little fracturing in the run-of-oven coke, which may mean excessive crushing costs. On the other hand, low shatter indexes

Generated on 2024-09-20 07:34 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

do not necessarily indicate optimum conditions or characteristics for the best domestic coke. The percentage through 1/2 inch in the shatter test is somewhat indicative of breeze formation during crushing and handling. The entire shatter test is highly empirical, however, and can be used only as a comparison to known values, determined after long experience and tests with many cokes.

8. TUMBLER TEST

The stability index (percentage on 1 inch) is a fair index of the amount of size degradation to be expected in handling and screening the various domestic sizes. However, the tumbler test is usually made on 2- x 3-inch uncrushed coke that may contain more or less natural fracture lines. During crushing and screening the coke may and probably will break along the fracture lines, and the resultant screened sizes may contain few fractures and be very strong. The stability factor, therefore, is only a fair index, as it is a measure of fractures in uncrushed coke.

The hardness factor (percentage on 1/4 inch) is a better index, as it indicates the actual hardness or abradability of the coke, which is not so much affected by fracture lines. It is not a good index for the amount of breeze produced, as other factors enter. It may be used as an indication of the amount of fine coke dust produced in crushing, screening, and handling and of the dustiness of the finished coke.

Both stability and hardness factors are highly empirical and can be used only in comparison with known values. No accepted methods of test for the various sizes of domestic coke are known to the writer, although adaptations of the shatter and tumbler tests are sometimes used.

9. SIEVE ANALYSIS

(a) Run-of-oven coke. - Little practical significance regarding the final screened product. However, the size of the run-of-oven coke is often a considerable factor in the wear of crusher teeth and the production of breeze. Large coke of a high shatter index requires more crushing and recrushing than smaller coke with perhaps a lower shatter index. More power is required, more breeze is produced, and more wear results.

(b) Domestic sizes. - Screen tests of the finished sizes show the effectiveness of the plant screens and the degradation of the product. Constancy or uniformity of sizing is important for several reasons. There is an optimum size of coke for a boiler or furnace of given size. Larger than optimum size causes the fire to go out in mild weather. Smaller than the optimum size restricts the draft and reduces the heat output of the boiler or furnace. Carbon monoxide loss and lowered efficiency may result from small or poorly sized coke, also, and the tendency to clinker formation is increased. Finally, off-sized coke may be noticed by the customer and result in a complaint from appearance only. Size tests are therefore important.

10. WEIGHT PER CUBIC FOOT

The bulk density is partly determined by the apparent specific gravity, although the sizing and the shape of the pieces are factors. The significance of the test is the same as discussed under 6.

11. DUSTINESS OF COKE

This test is significant, as it measures in part the dust resulting from coke firing, more so with hand-firing than with stoker firing. The satisfaction of a customer often depends on this factor alone.

In addition to the above A.S.T.M. tests, there are others which are or might be used for domestic coke. These are:

4402

Generated on 2024-09-20 09:01 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

1. IGNITION TEST

Success in maintaining very low fires in mild weather depends in part on the combustibility of the coke, which for domestic coke may be considered to be relative to the ignition temperature. Many kinds of tests have been used, at least one rather extensively. A simple, reliable test should be well worth while.

2. DIRTINESS OF COKE

The dustiness test measures the super-fine dust that floats in the atmosphere for an appreciable time. Contrasted to dustiness is dirtiness, which is the coarser dust, perhaps up to 20 mesh, adhering to coke. After the coke has partly dried out in the customer's bin, this dust sloughs off, collects on the floor of the bin and creates a dirt nuisance. A method of measurement should be of value.

3. SHAPE FACTOR

Appearance of the coke has no little effect on many customers' satisfaction with their fuel. A method of measuring the shape of the pieces (fingeryness, blockiness, roughness, etc.) probably would be accepted by many producers. The shape, particularly, is important in stoker firing, for the feeding of coke from a bin in small driblets is considerably affected by the shape of the pieces.

Generated on 2024-09-20 07:33 GMT / https://hdl.handle.net/2027/osu.32435030643688
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY